ELECTROMECHANICAL DESIGN

components & systems

9

AUGUST · SEPTEMBER 1958

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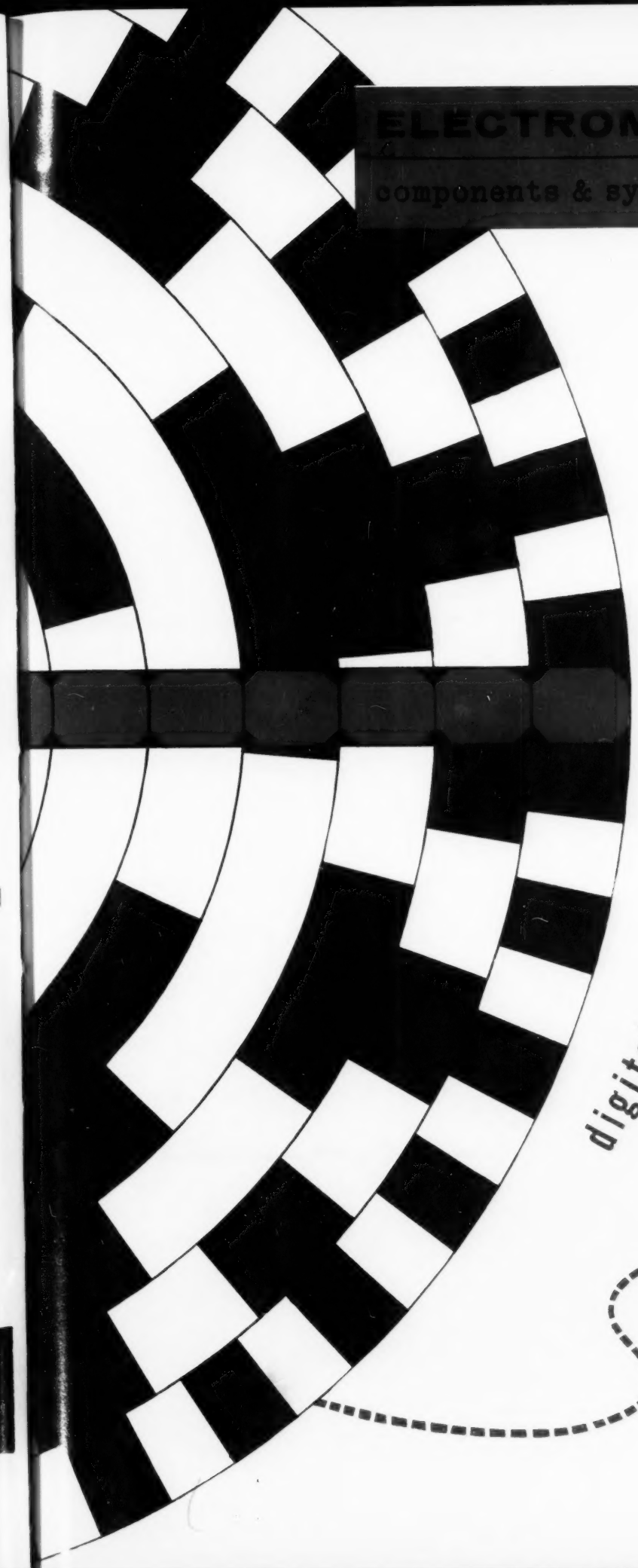
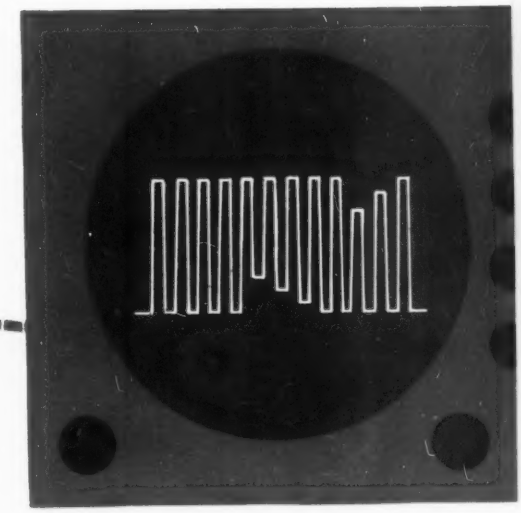
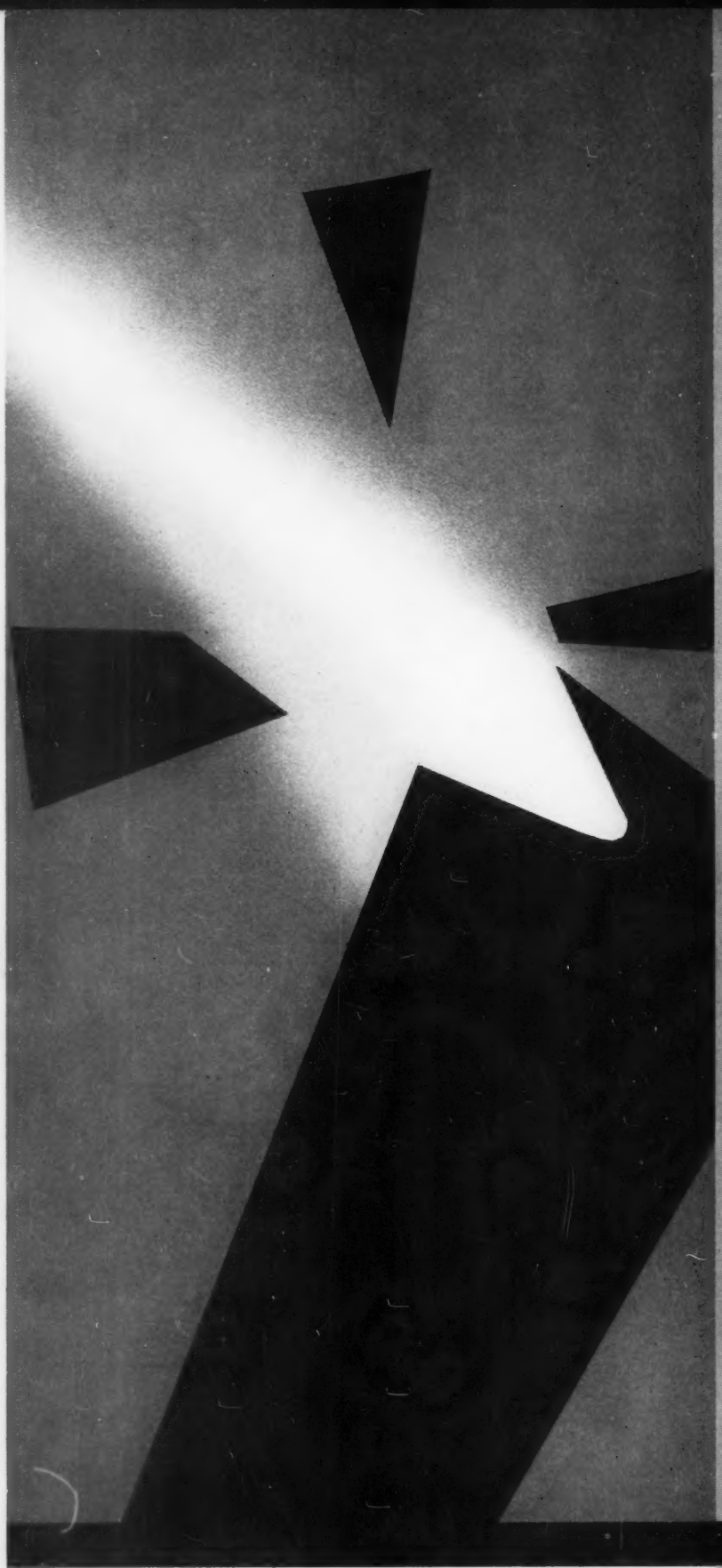


digital shaft-angle encoder



Flora



THE PLASMA JET—

a case of research and advanced development

Development of a re-entry simulation facility for the Air Force *Titan* ICBM nose cone required a method for heating air to extremely high temperatures. A special type of electrical discharge, sometimes called a "plasma jet," was considered. Both *fundamental* research—to obtain a quantitative understanding of the arc properties and mechanism—and *applied* research in actual aerodynamic and materials testing were needed. Advanced development—the actual design and construction of improved test facilities—was also an inherent part of the problem.

Theoretical and experimental physicists, aerodynamicists and physical chemists began a simultaneous attack on the fundamental processes. At the same time, and in close association with the others, instrumentation and mechanical engineers began to build and use a series of continually improved facilities for re-entry testing. Those inclined toward either fundamental or applied research in their particular specialty were able to maintain their integrity and their own research approach. At the same time they were able to benefit from the close working association with one another.

The results were especially fruitful. The plasma jet has proven an excellent tool for re-entry studies. Investigations of important applications in high-temperature chemistry, space propulsion and refractories are following as an added bonus.

Research and Advanced Development is more than a descriptive title at Avco. It is a concept that promotes creativity.

For information on unusual career opportunities for exceptionally qualified scientists and engineers, write to: Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Div., 201 Lowell Street, Wilmington, Mass.

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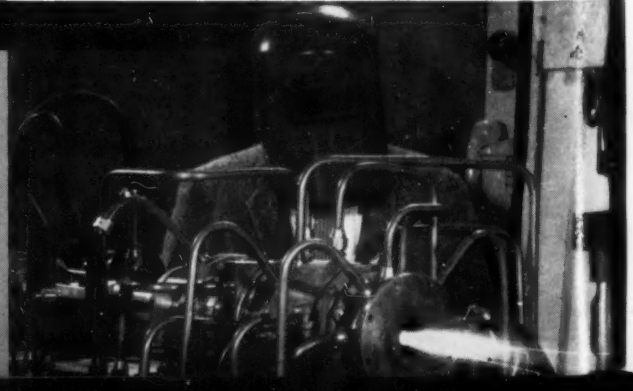

The

←CIRCLE

ELECTROMECHANICAL components & systems DESIGN 9

The Sourcebook of Design Ideas and Techniques in Applied Electromechanics

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Electromagnetic oscillation of outer bearing ring reduces both starting and running friction below 25 dyne centimeters—practically an irreducible minimum.

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Inexpensive "full-floating" piston design reduces size and weight and assures accurate alignment.

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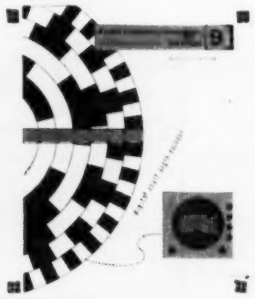
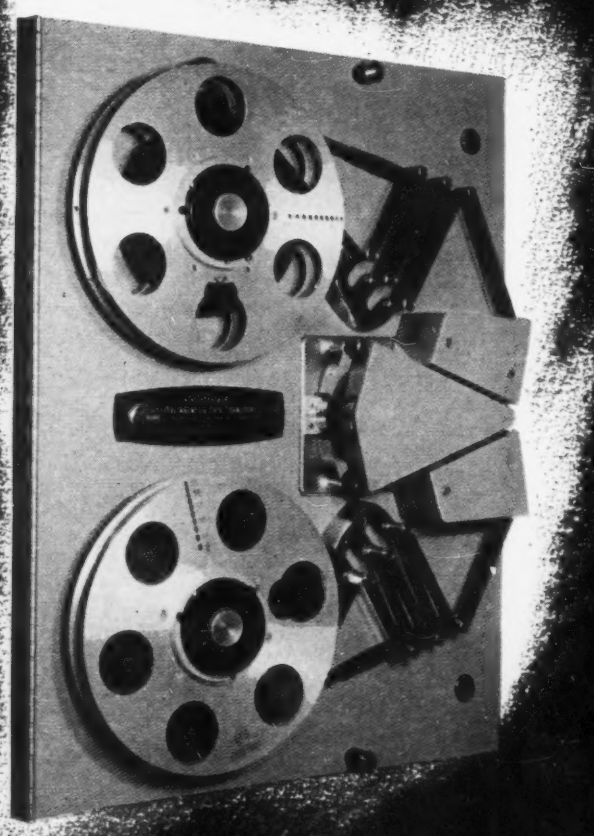


On this month's cover, James Flora, our Art Director, illustrates the coded disc of the optical shaft angle encoder described in the article starting on page 6.

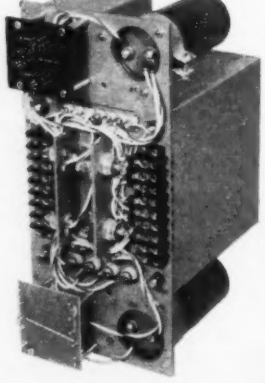
←CIRCLE 1 ON INQUIRY CARD



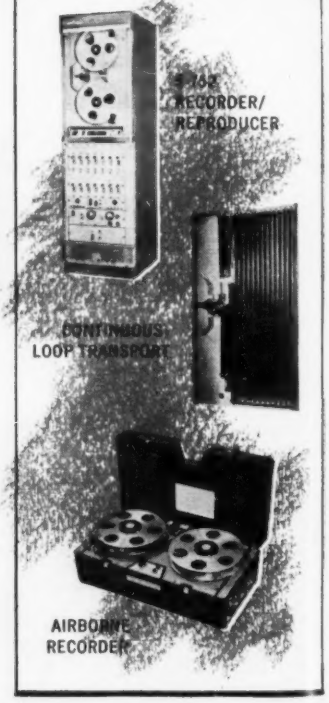
CEC announces the new DataTape digital magnetic tape recorder/reproducer

- *all transistorized electronics*
- *modular construction**
- *starts and stops in less than 5 milliseconds*
- *high-speed servo response*
- *continuous-duty servo motors*
- *all-metal-surface magnetic heads* (½" SPACING BETWEEN READ AND WRITE HEADS)
- *uses ½" to 1¼" tape*
- *10½" reels with NARTB hubs*
- *designed for standard rack mounting*
- *size: 19" wide by 24½" high by 13" deep*

NOW AVAILABLE... Not merely a laboratory instrument, but a fully ruggedized, reliable digital recorder designed for a whole gamut of industrial applications where long periods of unattended operation with minimum maintenance and down-time are paramount. Standardized speeds, track-width and spacing, and start and stop distances assure complete compatibility with other digital tape transports and handlers. *Contact your nearby CEC field office for complete information,* or write for Bulletin CEC 1608-X 12.



**Modularized components, such as Power Supply Unit at right, permit instant access and easy maintenance or replacement with minimum down-time.*



DataTape Division

CEC Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

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FOR MORE INFORMATION CIRCLE 2 ON INQUIRY CARD

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A BIRTHDAY PREROGATIVE

This issue of ELECTROMECHANICAL components & systems DESIGN, marking the start of our second year of publication, is an appropriate occasion for a needed change in publication date. Because of our mid-month publishing date, our Eastern Seaboard readers have been receiving the magazine on the third or fourth week of the month, and West Coast readers, as late as the first week of the following month. In effect, the magazine has appeared to be three to four weeks old when received. This appearance of tardiness is generally undesirable. We have, therefore, decided to advance the publishing date three weeks.

To us, the easiest way to solve this problem is by the simple device of changing the date identification of the magazine while maintaining existing publication schedules. Accordingly, we have combined the August and September issues into one publication. Hereafter the magazine will appear monthly at the beginning of the month—you should receive your October issue at the beginning rather than at the end of October.

IN OUR NEXT ISSUE

Next month's magazine, the October issue, will include the first of our Components Digest supplements—a handbook and buyers' guide on instrument servo motors.

Components Digest, as described generally in the editorial of our June issue, constitutes a new kind of technical reporting that will present key facts on commercially available electromechanical, electrical and mechanical components in compact usable form for the electromechanical engineer. It will contain electrical and mechanical theory, design data and selection factors for families of components, and will include pertinent standards, bibliographical references and buyers' guide information.

Our editors will attempt to obtain internal company reports and other sources of unpublished data to amplify the normally available material. We will maintain a critical engineering viewpoint in the analysis and calculation of all engineering data. Each Components Digest supplement will cover either one or several topics, depending upon its scope. Topics will always appear on separate sheets to permit the reader to organize these sheets in a loose leaf binder or other filing device. As new data accumulate on topics previously covered our editors will issue up-to-date additions to the Components Digest to maintain the usefulness of the previously published material, so that as time goes on a complete and continuously up-to-date file on each class of components will exist. As a result our readers will often be able to make component selections from a single source of information, subject to confirmation by direct contact with several manufacturers tentatively selected from the Components Digest.

ROBERT B. BROTHERSTON
Editor

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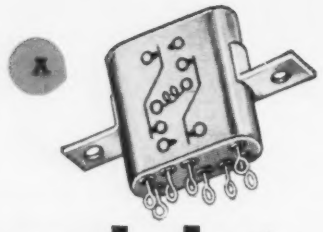
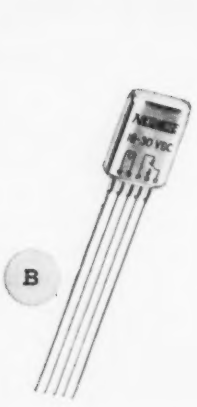




sub-miniature relays with high performance characteristics

A
MV
crystal can size

Vibration: 10 to 34 cycles per second at maximum excursions of .4". 34 to 2000 CPS 20G's acceleration.
Weight: 0.45 ounce (max.)
Size: .875" high x .797" wide x .359" thick max.
Pull-in Power: 250 milliwatts at 25°C.
Contact Rating: 2 Amps resistive at 32 VDC or 115 VAC.

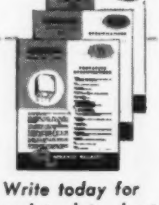
B
NM
the famous NEOMITE

Vibration: 10 G to 500 cps.
Weight: .09 oz.
Size: H: .530" ±.015; W: .392" ±.010"; D: .196" ±.010"; Lead length: 1.5" ±.0625".
Pull-in Power: 100 Milliwatts.
Contact Rating: .25 Amp at 28 VDC resistive load.

C
... and announcing the brand-new
VG

Vibration: Low Frequency—10 G's, 10-55 CPS (total max. excursion, .06").
High Frequency—15 G's, 55-2,000 CPS.
Weight: 1.5 ozs., approximately.
Size: 7/8" ±1/64" sq. x 1 1/8" ±1/64".
Pull-in Power: 340 Milliwatts at 25°C.
Contact Rating: 5 Amps at 26.5 VDC or 115 VAC, 60 Cycles resistive load.
Shock: 100 G's, per MIL-R-5757C, Shock Test II.

Advance Sub-miniature Relays are ideal for critical aircraft and missile applications. They feature small size, low weight, and high-precision performance. All have low power requirements.



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FOR MORE INFORMATION CIRCLE 3 ON INQUIRY CARD

LETTERS

New York, N.Y.

We greatly appreciate the interest you have shown in the Chromatron color tube by the article in the June 1958 issue of your magazine. You should be complimented on the concise outline of the factors governing the Chromotron.

I wonder if I may ask you to correct an erroneous impression which I am certain was quite unintentional. The trademark "Chromatron" is not owned by Litton Industries but is the property of Chromatic Television Laboratories, a division of Paramount Pictures Corp. . . .

Borge Hansen-Moller
Chairman Executive Comm.
Chromatic Television Laboratories

• • •

Ithaca, N.Y.

There is a small omission in the article written by myself for the April issue of ELECTROMECHANICAL DESIGN. A term αET should be subtracted from the $\sigma\theta$ expressions in Equations (4) and (5). This now means that, in the example

$$\overset{\sigma}{\underset{r\text{-}r_1}{\theta}} = 2.591\ E\ \alpha\ T_i = 505\ T_i$$

Prof. H. D. Conway
College of Engineering
Cornell University

• • •

West Orange, N.J.

I have read with considerable interest an article entitled "The Right Battery for the Job" on page 46 of your May 1958 issue.

While your magazine is circulated in industries where Edison Nickel-Iron Alkaline Storage Batteries do not find their major markets, nevertheless the article as written is misleading . . .

I wish to point out that the Edison Nickel-Iron Alkaline Storage Battery is more extensively used and the total dollars in sales per annum exceed those of all the other alkaline types which were listed in the article . . .

We have noted with considerable interest the article which except for omission of reference to the Edison Battery appears to be very well prepared.

R. H. Weeks, V.P. and Div. Mgr.
Storage Battery Div.
Thomas A. Edison Industries

• • •

Clifton, N.J.

Both Mr. Fred Keller, Bright Star Director of Engineering, and I were very much interested in your recent article regarding batteries. We both noted, however, that only a very short paragraph was given to dry batteries

their place in the industrial field. h of us feel, very strongly, that any cle regarding battery application uld have a substantial portion dedi- ed to the dry battery field since se batteries are still the "work horse" the industry . . .
bert Frost, Pres.
ght Star Industries

• • •

New York, N.Y.

thoroughly appreciated your ex- ent coverage of the battery industry "The Right Battery for the Job" ay 1958) . . .
n connection with the performance rts presented, however, there are few points concerning silver-zinc teries that should be brought out:
1. You stated that the cycle life of se batteries went "up to 20 cycles". ld results have shown, however, t our Silvercel batteries deliver up *200 cycles*!
2. You also made the statement t one of the limitations of silver-zinc teries was "poor shelf life". How- r, one year has always been con- ered good for batteries—and, in ac- l field tests, Silvercel batteries, when perly stored, have delivered up to *ears' shelf life!*
Referring to silver-cadmium bat- es you also said that their cycle life t up to 500 cycles. While this ght have been true when the article s prepared . . . engineers are now orting *1000 cycles from our Silcad teries!*
be Werba
dney Electric Corp.

• • •

Pacific Palisades, Calif.

ny article, "Tactile Communication tem for Control of Aircraft", ques- s have arisen as to the operation of "collision anticipator". Particularly, does the plane receive the infor- tion? The article states that tactile nals of increasing frequency indicate the pilots they are flying on a colli- n course and that tactile signals of reasing frequency indicate they are ng away from a collision course. By ng the Doppler principle such sig- s can be automatically received by h plane—as the airplanes move to- her, the apparent pitch to each re- ing plane is greater than the fre- ncy emitted by each plane, and as airplanes move away from each er the apparent pitch is less than frequency of the vibrating source. h planes would have UHF trans- ters of 7 to 11 mile range and quency difference multipliers. This thod would provide a reliable, low t emergency warning system.
eph Hirsch

CIRCLE 4 ON INQUIRY CARD→

Important Features of AMPHENOL MINNI E CONNECTORS

actual size

1

The "E" construction of AMPHENOL's miniature, multi-contact electrical connectors *pass a tough,* new *altitude-moisture resistance test* which accurately simulates performance conditions in new aircraft and missiles. Connectors are submerged in salt water and altitude-cycled to 80,000 ft., to 65,000 ft. and then returned to room ambient pressure. Cycle lasts one hour; test is comprised of ten cycles. At the end of the test AMPHENOL ***MINNI E's*** have a minimum insulation resistance of 1000 megohms, approximately ten times greater than that acceptable under MIL-C-5015C after moisture.

2

MINNI E's have *stainless steel* bayonet slots and pins, providing greater durability and eliminating the wear encountered with "hardcoat" and similar surface treatments of softer base metals.

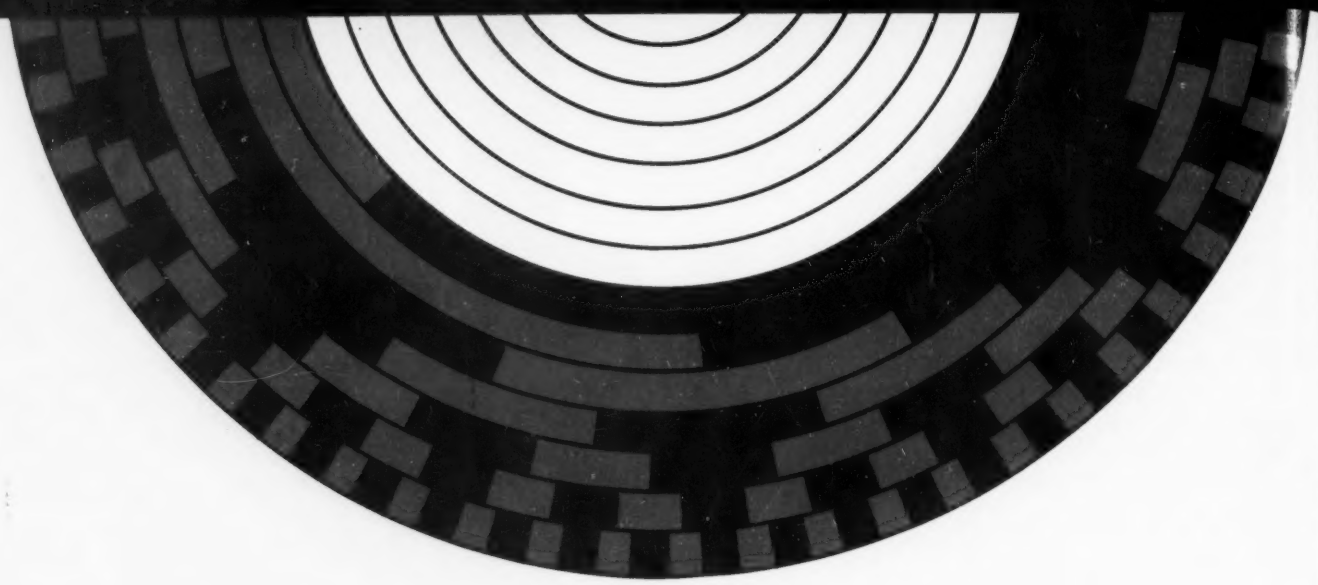
3

Both #16 and #20 size socket contacts in ***MINNI E*** connectors *resist test prod damage.* The entering end of the socket has a one-piece stainless steel hood that excludes the entrance of a pin .005" larger than the diameter of the mating male contact.

AMPHENOL's *Authorized Industrial Distributors stock* MINNIE *and other standard components, provide immediate service.*

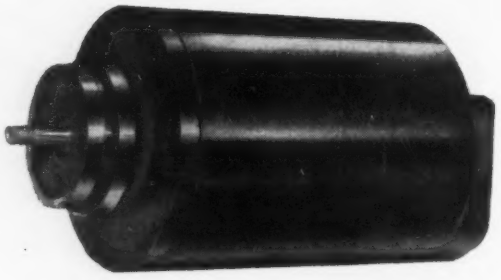
AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois

AMPHENOL



DIGITAL SHAFT ANGLE ENCODER

Design for Custom Precision in Production

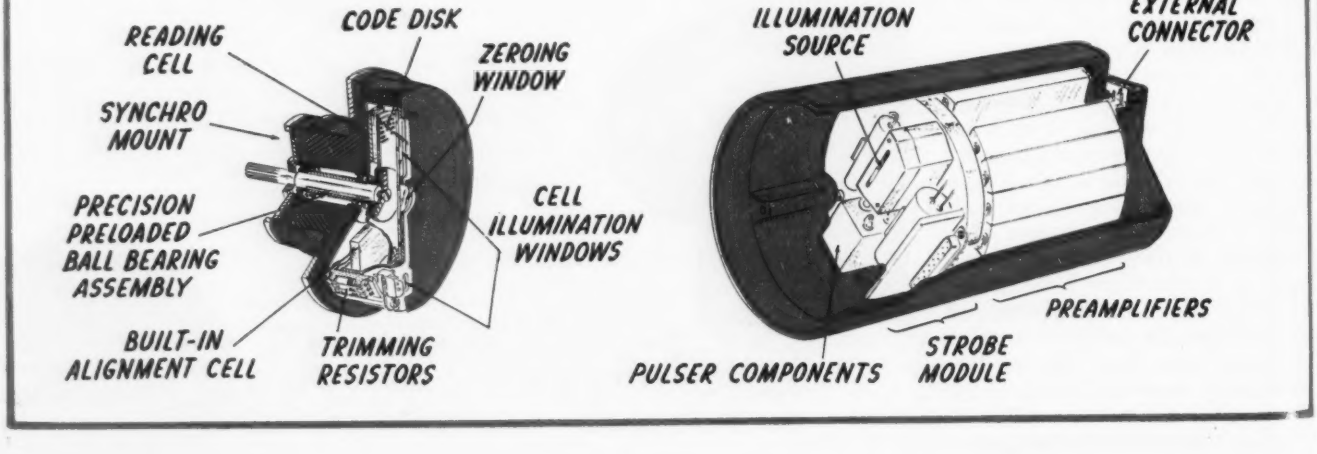


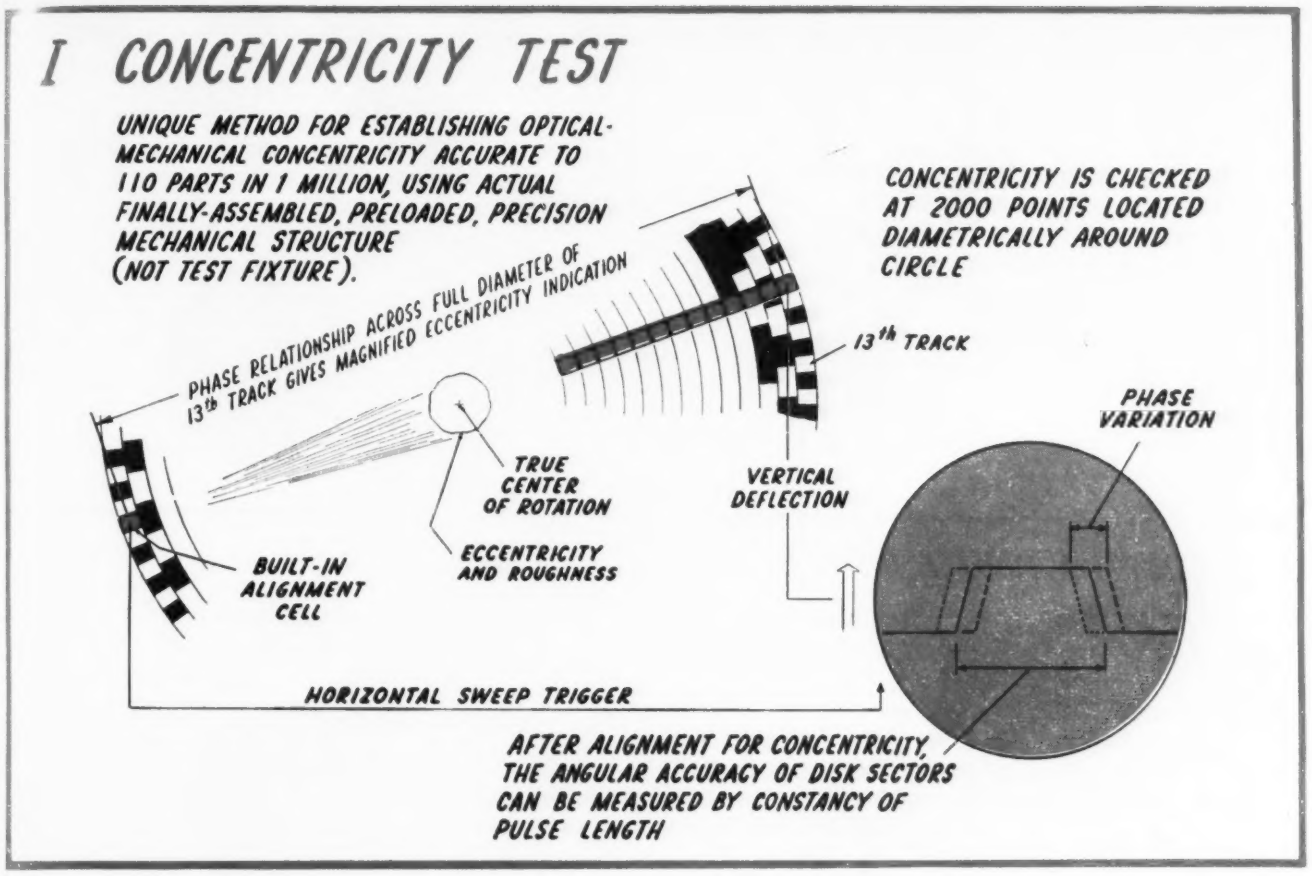
An alignment cell built into this shaft-angle-to-digital converter makes possible angle indication accurate to better than ±2.5 minutes of arc in a production model. At 366 rpm, probability of 1-bit error, representing only —1.3 minute maximum angular error, is 0.75.

Until very recently precision optical encoders for converting shaft angle to digital indication have been built on a limited basis—to fit a specific job. Only recently have designers attempted to put such encoders on a production basis, with full production quality controls. The Dychroverter Model DV-13A, designed by Dychro Corp., Newton, Mass., now fulfills this objective by introducing means of control over the device both during manufacture and in the field. It contains a built-in alignment cell for establishing optical-mechanical concentricity precise to 110 parts per million.

ENCODER DESIGN

The encoder employs a coded transparent disk with a cylic (Gray) binary pattern in thirteen concentric tracks. Shaft-angle code is read by means of an optical system having a radial-slit flash-lamp illumination source, a corresponding radial array of thirteen light detector cells, and thirteen associated preamplifiers. The alignment cell is mounted diametrically opposite the 13th (or outermost) cell in the "reading" array (see Test Diagram I).




I CONCENTRICITY TEST
UNIQUE METHOD FOR ESTABLISHING OPTICAL-MECHANICAL CONCENTRICITY ACCURATE TO 110 PARTS IN 1 MILLION, USING ACTUAL FINALLY-ASSEMBLED, PRELOADED, PRECISION MECHANICAL STRUCTURE (NOT TEST FIXTURE).
CONCENTRICITY IS CHECKED AT 2000 POINTS LOCATED DIAMETRICALLY AROUND CIRCLE
PHASE RELATIONSHIP ACROSS FULL DIAMETER OF 13th TRACK GIVES MAGNIFIED ECCENTRICITY INDICATION
13th TRACK
PHASE VARIATION
TRUE CENTER OF ROTATION
VERTICAL DEFLECTION
ECCENTRICITY AND ROUGHNESS
BUILT-IN ALIGNMENT CELL
HORIZONTAL SWEEP TRIGGER
AFTER ALIGNMENT FOR CONCENTRICITY, THE ANGULAR ACCURACY OF DISK SECTORS CAN BE MEASURED BY CONSTANCY OF PULSE LENGTH

Heart of the mechanical structure is a pair of special duplex instrument-precision bearings, machine matched for identity and parallelism. Tolerances are in the order of millionths of an inch to achieve a specified preload. The bearing set, including custom spacers, is installed only once and is never removed or shimmed. The coded disk is referenced to the photo-optics through solid precisely-controlled surfaces.

After assembling the mechanical structure of the instrument, Dychro preloads the bearings in the exact mechanical environment in which they will operate. They then install the critical coding disk, mechanically align it through the sensitive phase-measurement procedure described in Diagram I, and seal it permanently in place. They thus make allowance simultaneously for all sources of rotational eccentricity and eliminate inaccuracies customarily introduced by use of secondary alignment fixtures. The built-in alignment cell is always available to check optical performance, test mechanical concentricity, and study effects of severe environmental use. Diagrams II and III show how radial alignment of the reading cells and surface inspection of the disk can also be tested after assembly of the unit.

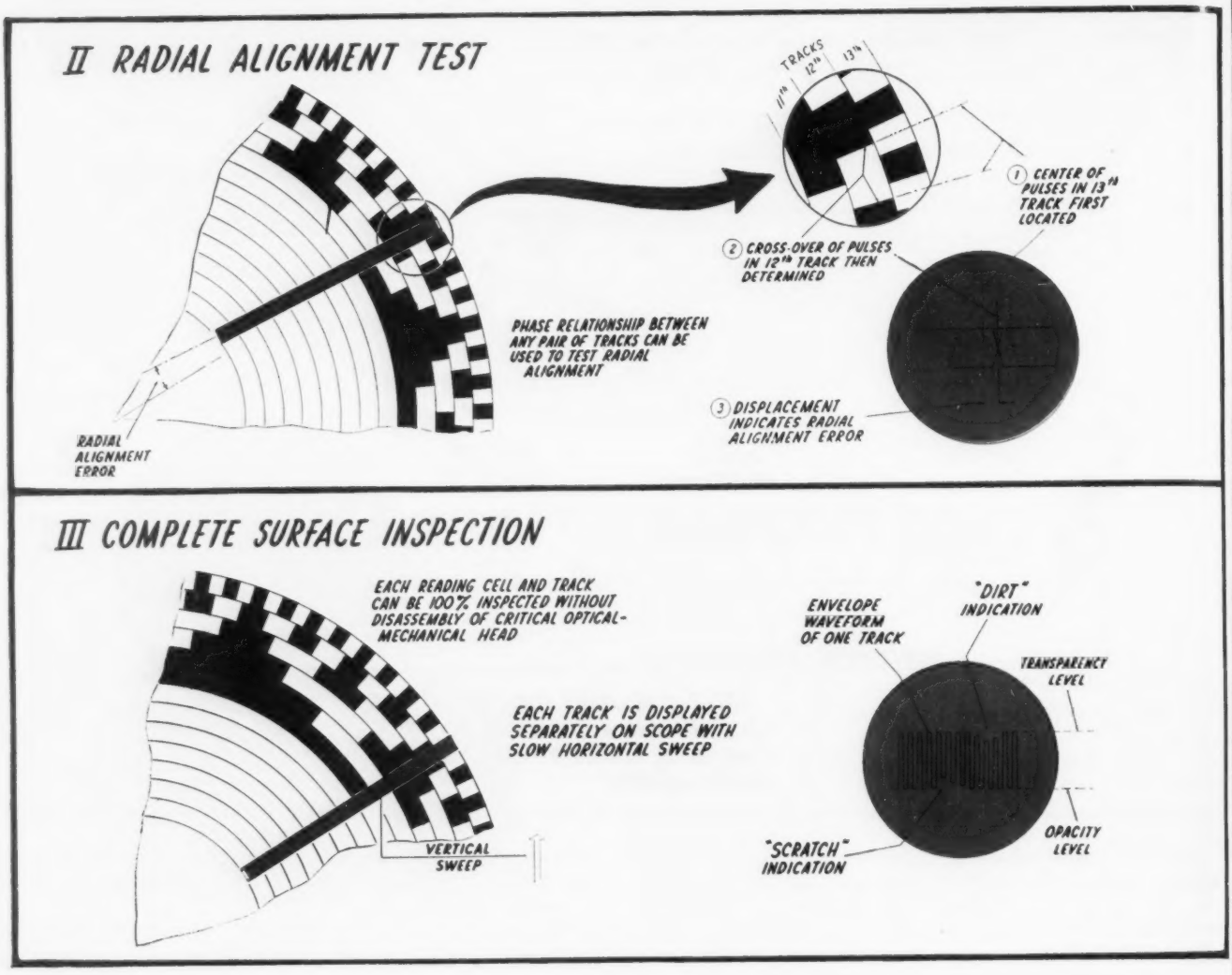
IMPORTANCE OF CENTERING THE DISK

The function of a digital shaft-angle encoder is to read a specific shaft-angle from a zero reference position. This requirement makes centering the coded disk supercritical because any motion of the center of the code pattern away from the actual center of rotation of the pattern, due to shaft motion resulting from bearing inaccuracies or loadings on the shaft, has the same effect as mounting the readout on a spring or something loose. Any motion of the center of the disk is absolutely and directly an error in angular measurement. To control the centering of the disk means to have a shaft that's exceedingly straight, to have bearings that have exceedingly low eccentricities, and to position the disk on the true center of rotation of the bearing shaft assembly very precisely.

If centering alignment is not accomplished within the converter, it is generally necessary to use an auxiliary alignment fixture of some sort. But this technique necessarily involves, after the disk is centered on the shaft, removing the disk and shaft from the bearings on the assembly jig, and installing this disk and shaft on the bearings of the actual encoder where it will be used. As a result, instead of correcting for the eccentricities of the final unit, you add those of the test unit. You end up with the combined eccentricities of the two bearing structures in the disk alignment.

By building the alignment cell into the encoder, Dychro engineers have made the unit itself the alignment fixture. Charles G. Beaudette, Chief Engineer of Dychro Corp., points out that this design has many advantages. "Using the alignment cell in the final unit," he said, "we can align the center of the code pattern, not to the center of the shaft, but to the true center of rotation of the shaft bearing assembly. Any eccentricities in the bearings or any difficulties in the shaft or assembly are thereby automatically compensated and the reading we get on our scope is a true reading of the centering of the disk. If there is any difficulty with bearings, dirt, or trouble of that sort, it will show up and we can reject the unit at that point. The feature of leaving the cell in the equipment when it's shipped—we've never considered removing it—means that the customer has a complete testing facility built in. He can set up a very rigid, incoming inspection control. At any time, for example, after environmental testing, after the unit has been manhandled, dropped or otherwise hurt, or at any time just for the general purposes of checking, he can test the unit to see if it is measuring angles within its specified accuracy."

continued on page 8


II RADIAL ALIGNMENT TEST
TRACKS
11th
12th
13th
1 CENTER OF PULSES IN 13th TRACK FIRST LOCATED
2 CROSS-OVER OF PULSES IN 12th TRACK THEN DETERMINED
PHASE RELATIONSHIP BETWEEN ANY PAIR OF TRACKS CAN BE USED TO TEST RADIAL ALIGNMENT
3 DISPLACEMENT INDICATES RADIAL ALIGNMENT ERROR
RADIAL ALIGNMENT ERROR
III COMPLETE SURFACE INSPECTION
EACH READING CELL AND TRACK CAN BE 100% INSPECTED WITHOUT DISASSEMBLY OF CRITICAL OPTICAL-MECHANICAL HEAD
EACH TRACK IS DISPLAYED SEPARATELY ON SCOPE WITH SLOW HORIZONTAL SWEEP
VERTICAL SWEEP
ENVELOPE WAVEFORM OF ONE TRACK
"DIRT" INDICATION
TRANSPARENCY LEVEL
OPACITY LEVEL
"SCRATCH" INDICATION

APPLICATIONS

Without the use of brushes or moving contacts, the Dychroverter can instantly encode the angular position of high-speed rotating shafts. It is especially useful in measuring the angular position of a shaft that is intrinsic with a system, for instance, the azimuth shaft in a radar antenna. Very often you want to measure its angle from true north.

The encoder is useful as the feedback element in digital shaft-positioning servomechanisms, to couple rotating analog devices into digital computers and for converting two-speed analog shaft data into a single, linear, digital word for data processing. By using Dychroverters in a feedback loop to position one-speed or two-speed sine-cosine resolvers, digital angle information can be quickly converted to a precise one-speed or two-speed sine-cosine voltage. In real-time systems, as much as 20 milliseconds computation time can be saved by the use of this sine-cosine generation technique.

Another application would be that of placing a precision gear on a primary shaft, such as that of a radar antenna, azimuth or elevation shaft, and connecting one of these encoders in a geared up fashion, so that it makes 100 turns per complete turn of the antenna. A second encoder placed directly on the shaft would tell you which turn of the 100 turns the fine converter is in. The two converters together would read out a complete digital angle.

Electrical output of the Dychroverter is 5 volts for a "one", and less than 50 millivolts for a "zero", thus providing a high and reliable one-to-zero ratio. Readout is possible up to a maximum reading rate of 100 complete digital words per second. Output impedance ranges from 100 to 250 ohms. Model DV-13A has a Size 23 synchro mount, an outside diameter of 3¾ inches, an over-all length of 7½ inches, and a weight of 5 pounds. Angular reading accuracy is maintained in ambient temperatures from −65° to +165° F, and in relative humidities of 95%. The unit is operable within specification under shocks up to 20 Gs, and vibrations of 55 cps with a 0.015-inch amplitude.

Circle 225 on Inquiry Card

WORTH FILING

Infrared Spectrophotometer

24-page brochure on the Infracord double beam infrared spectrophotometer describes what infrared is and how it is used for the identification of unknowns, qualitative and quantitative analysis, and product control. The design, specifications and performance of the Infracord are thoroughly described. Typical spectra illustrate the performance characteristics. Complete line of accessories available for the instrument also are illustrated and their use described. These include sealed cells, mirocells, gas cells, KBr dies and variable space cells. More than twenty fields where infrared analysis finds broad application are listed, with a brief description of how the technique can be used.

Source: Perkin-Elmer Corporation, Norwalk, Connecticut

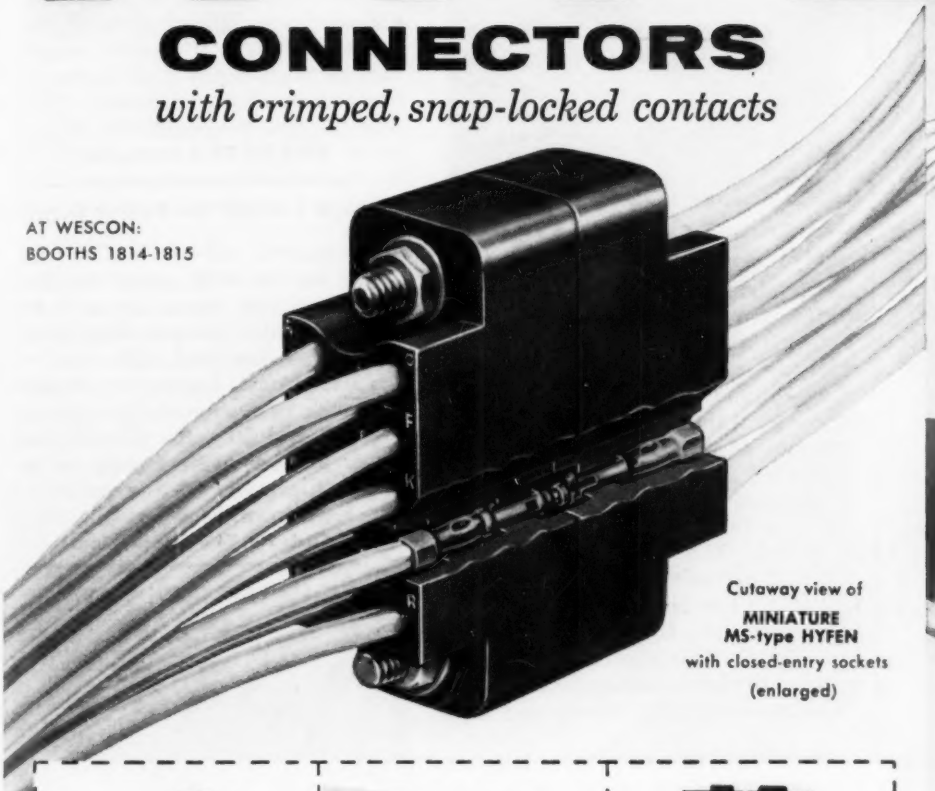
For your copy: Circle No. 121 on Inquiry Card

HYFEN™

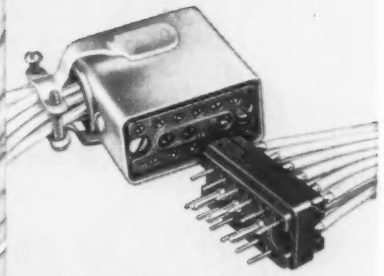
CONNECTORS

with crimped, snap-locked contacts

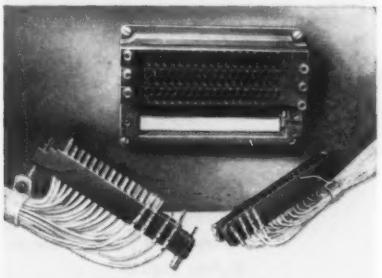
AT WESCON:
BOOTHS 1814-1815



Cutaway view of
MINIATURE
MS-type HYFEN
with closed-entry sockets
(enlarged)

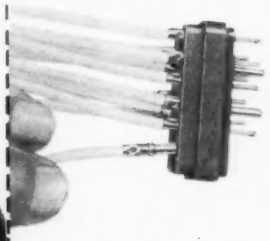


15 contact, multi-purpose connector. Mates with, or replaces existing solder connectors.

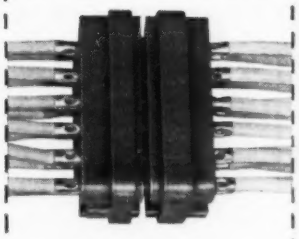


Feed-thru, modular design, multiple insert connector. 35 contact inserts, can be removed from frame for easy contact insertion or removal. 5 or 8 insert frames available.

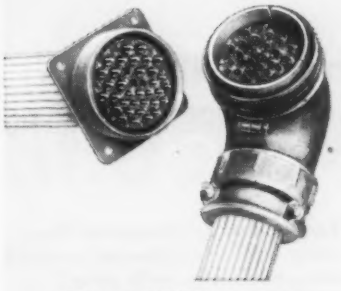
CRIMP pins or sockets on wire



SNAP-LOCK contacts into plug or receptacle



MATE with HYFEN or equivalent solder types



AN-type HYFEN connector, showing HYFEN method adapted to round design.

SAVE WEIGHT, SPACE, TIME—Burndy's HYFEN method brings added Reliability and Versatility to the connector field, allowing the design of lighter and more compact equipment...saving space, weight and time. Pins and Sockets can be bench-installed on the wire and can be snap-locked in place even after the Plug and Receptacle have been mounted on the equipment.

Designed to replace or mate with virtually all existing connectors, including AN, MS, and other Miniature types, the HYFEN meets or exceeds MIL specs.

The HYFEN method ends the high rejection rate inherent with the use of solder ...especially important in today's continuing trend toward miniaturization.

HYFEN types illustrated are typical of those already supplied to the Industry by Burndy. HYFEN connectors are engineered to meet specific requirements. For other types and sizes, contact Burndy.

OMATON DIVISION

BURNDY

For detailed information Write or Wire **BURNDY**, Norwalk, Connect., or Toronto, Canada...in Europe: Antwerp, Belgium 58-14

FOR MORE INFORMATION CIRCLE 5 ON INQUIRY CARD

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

types: ALL INSULATIONS
including polyvinyl chloride; asbestos; silicone rubber; Teflon; Kel-F; polyethylene; Nylon; etc.

conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

source: CONTINENTAL WIRE CORPORATION

For complete information on the many types of Continental insulated wires and cables, write or call CONTINENTAL, Wallingford. Where heat . . . moisture . . . cold . . . oil . . . grease . . . corrosive vapors . . . demand a reliably insulated wire or cable, be sure to specify CONTINENTAL. A wide range of types and sizes in stock, or to special order. Give amperage, voltage, diameter limitations, and operating temperatures and conditions when inquiring.

continental wire corporation

WALLINGFORD, CONN. / YORK, PENNA.

CIRCLE NO. 6 ON INQUIRY CARD

Subminiature Capacitors and Relays

New subminiature ceramic capacitor with high reliability over a broad temperature range and a new microminiature relay designed for maximum vibration and shock resistance will be exhibited at the 1958 Wescon by Telecomputing Corporation.

The subminiature ceramic capacitor is designed for highest capacity per unit area for applications where space is critical. The tiny unit is rated at 200 working volts d-c. Capacity variation is ±10 percent of room temperature capacitance in a range from −55° to +150°C. This stability results from a new production-controlled ceramic dielectric with high density and high K.

The microminiature relay is designed for applications where size and weight are critical. Life expectancy exceeds 1,000,000 cycles at the full non-inductive contact load of 2 amps, 28 volts dc at 125°C ambient. On dry circuits a minimum of 10,000,000 operations are guaranteed.

The relay is hermetically sealed for operation from sea level to 100,000 feet altitude at −65°C to +125°C. Standard 15G relays and models for vibration loads exceeding 30G are available. Telecomputing Corp., Los Angeles, Calif.

Circle No. 78 on Inquiry Card

WORTH FILING

Inductive Pick-Offs

May-June 1958 issue of Giannini Technical Notes has as its feature article "Inductive Pick-Offs", which discusses a-c output instruments, and the reliability and stability of inductive pick-offs. Schematics of typical voltage output inductive pick-off circuits are shown. Also discussed are the missile and its guidance system, Giannini's free gyro and new standard line of potentiometers.

Source: G. M. Giannini & Co., Inc.
Pasadena, California
For your copy: Circle No. 107 on Inquiry Card.

Miniature Rotary Switch

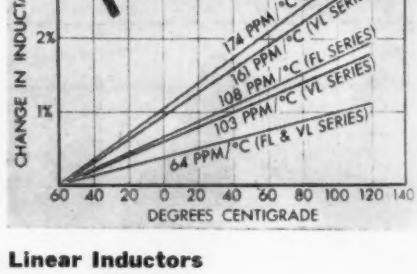
New miniature rotary switch provides 30° indexing, 12 contact positions, up to 5 sections and current-carrying capacity of 3 amperes. Interrupting rating is 1/2 ampere 115 volts a-c. The switch can be furnished with up to six poles per section; rotation may be unlimited, or limited from 2 to 12 positions. It is 3/4" square; maximum back-of-panel depth is 2¾ inches. R-F Electronics Inc., Division Electro Switch Corp., Weymouth 88, Mass.

Circle No. 73 on Inquiry Card.

Voltage Limiter for Power Supplies

Instantaneous, all-electronic voltage limiter for use with power supplies is used to protect transistors, and other voltage sensitive devices, from damage due to both low- and high-speed voltage excursions. Limiter is adjustable to provide protection at any voltage between 0 and 50 volts. It will handle power supplies with ratings up to 3 amps. Electronic Measurements Co., Inc., Eatontown, New Jersey.

Circle No. 74 on Inquiry Card



Linear Inductors

Adjustable and fixed linear inductors offer a marked improvement over conventional toroids in several respects. Designed to replace toroids in wave filters, resonant circuits, impedance choke applications, and resonant transformer applications, variation of inductance in the inductors is absolutely linear from −55 C to +125 C. Temperature coefficients of 53 ppm to 161 ppm are available and the new inductors are self-compensating with polystyrene foil capacitors in resonant meshes.

Linear inductors have a higher Q over a wider range, typically, 500 at 50 kc, and they are more astatic than toroids and possess a lower external field. Other advantages include low price, small size, Q variation of ±10% from −30 to +85 C, inductance range of 100 uh to 2H. Pulse Engineering, Inc., Redwood City, California.

Circle No. 100 on Inquiry Card

Electro-Poise Miniature Relay

Miniature relay features an increased magnetic force that provides higher contact pressures and greater travel than are usually found in relays of this type. For low level circuit or general purpose use, the unique design incorporates a solenoid type of magnetic assembly with two dynamically balanced plungers. Each relay is counterbalanced and the contacts are isolated from the coil in a separately sealed contact chamber. Each relay is assembled under ideal conditions in an air-conditioned, pressurized room that eliminates any possibility of contamination.

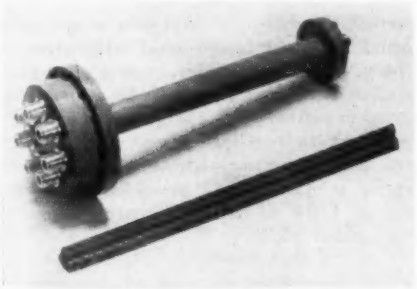
Designed to meet the most exacting modern requirements for a miniature 6 P.D.T. hermetically sealed relay, it will meet MIL specifications and drawings for this type of equipment.

Its general characteristics include a rated load of 2 amperes, 28 volts, D.C. resistive; an ambient temperature range of −65° C to 125° C; a vibration of 15g to 2,000 cps with no contact chatter; and a shock resistance to 50g, 11 milliseconds. Price Electric Corporation, Frederick, Maryland.

Circle No. 127 on Inquiry Card

General Purpose RF Power Dividers

Series of new general purpose 100-200 and 200-400 Mc Dividers connect 2 to 12 loads to a single source. Units contain broadband matching transformer. Input VSWR is less than 1.25. Loss is about 1/10 db. They are rugged and completely weatherproof. Power rating is 500 watts at 150° F ambient. Special units are available for other frequency bands and for power levels up to 100 kw, as well as for lower VSWR.



These RF Power Dividers are used for connecting a simple 50-ohm source to as many as twelve 50-ohm leads. Each divider contains a low loss matching transformer section to minimize mismatch. These units are suitable for outdoor environments and airborne applications and are completely pressurized. Adams-Russell Co., Inc., Cambridge, Mass.

Circle No. 79 on Inquiry Card

THE ALL PLASTIC VALVE THAT

DEFIES CORROSION

VALCOR's all plastic, corrosion-resistant solenoid valve, SV-5100 series, is the only solenoid valve that has no metal contact with the fluid—ever. Specifically designed to handle most of the corrosive media so widely used in industry, VALCOR's new, all plastic solenoid valve will, in many cases, outlast stainless steel valves 100 to 1.

If you have a corrosive media problem, from sulphuric acid solutions to citrus juices, try this new VALCOR valve on your toughest application. Prove for yourself how this new valve defies corrosion. List prices start at $8.50.

IMPORTANT: Hundreds of other valve variations, in design and pressure ratings, are inherent in this new SV-5100 series. By incorporating some of the very newest engineering and chemical formulas, we can offer valve variations designed to meet almost any corrosion problem you might be faced with.

Write today for new catalog sheet. For specific information, please send us pertinent application details.

VALCOR ENGINEERING CORP.

5374 CARNEGIE AVENUE, KENILWORTH, NEW JERSEY

VALCOR SOLENOID VALVES

FOR MORE INFORMATION CIRCLE 7 ON INQUIRY CARD

Miniaturized version of Barden Dynamic Bearing compared with first production model. An electromagnetic device oscillates the outer ring of the supporting bearings. This action tends to cancel out friction torque resisting rotation of the supported member.

TORQUE-FREE BEARING ASSEMBLY

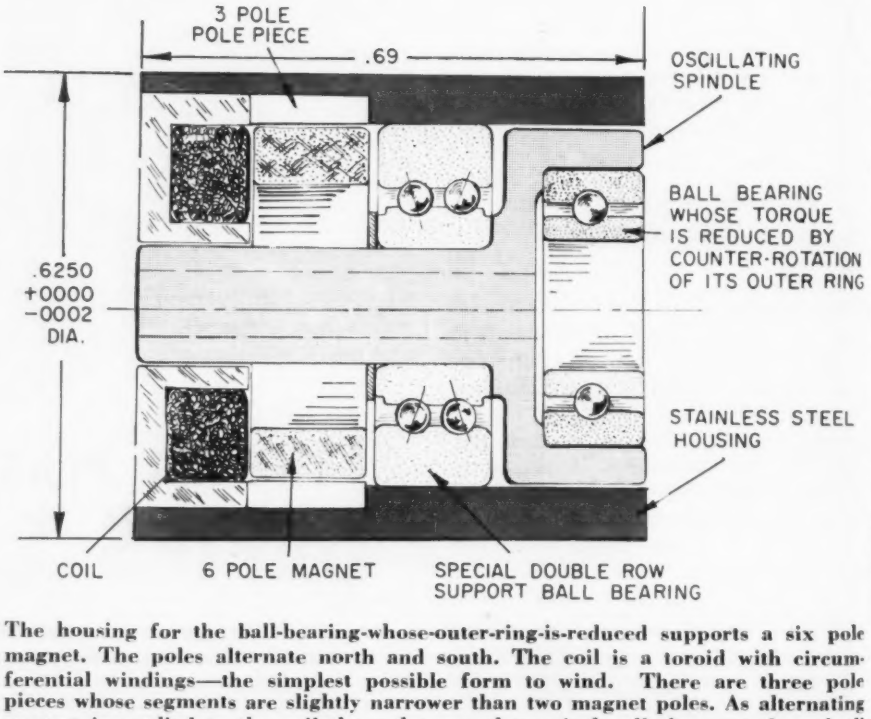
Electromagnetic Oscillation of Outer Bearing Ring Minimizes Friction

In repeated laboratory tests, Barden Dynamic Bearings have consistently shown starting torque equal to running torque, with both below 25 dynecentimeters. Endurance tests showed no increase in torque after 1000 hours of operation.

In operation, an electromagnetic device oscillates the outer ring of the supporting bearings. This action tends to cancel out the friction torque resisting rotation of the supported member. The effective resistance to rotation is the residual of clockwise torque subtracted from counterclockwise torque. This residual, which is the torque of the Dynamic Bearing, is the restraint caused only by viscous effects, practically an irreducible minimum. For accurate positioning of the supported load, Dynamic Bearings can be preloaded, with torque still being well below the torque level of conventional bearings that are not preloaded.

The Dynamic Bearing, manufactured by the Barden Corporation, Danbury, Conn., makes available for the first time a rugged, self-contained ballbearing assembly that closely approaches the minimum friction achieved by such delicate mechanisms as knife edges, jeweled pivots or flotation devices.

Indicated applications for the Dynamic Bearing are gyro gimbals, scales, static balancing machines, gyro-stabilized platforms or other precision devices where a low-torque but practical support bearing is needed. Maximum benefits are derived at very low velocities—those approaching zero RPM.



The housing for the ball-bearing-whose-outer-ring-is-reduced supports a six pole magnet. The poles alternate north and south. The coil is a toroid with circumferential windings—the simplest possible form to wind. There are three pole pieces whose segments are slightly narrower than two magnet poles. As alternating current is applied to the coil the poles are alternatively all three north and all three south, causing the magnet and its support to oscillate about 22½°. The driving frequency is chosen which produces maximum amplitude of oscillation when the system is in resonance. The magnet is Alnico VI; precision grinding this to ten-thousandths tolerances from the ± 1/64 as-cast tolerances requires special grinding wheels and considerable operator skill.

Background for the new bearings and some problems in their development were described for us by Barden V.P.—Engineering, Bruce L. Mims.

The idea of oscillating one ring of a ball bearing to reduce or eliminate static friction dates back at least to 1907 when H. Anschütz-Kaempfe was granted a patent (841612) incorporating this idea in a magnetic compass suspension. About ten other patents incorporate this basic theme. Recently Sperry Rand applied the idea in a directional gyroscope and gave it the trade-name Rotorace. In all these devices gear drives are incorporated in the instrument to oscillate the ball bearing whose friction is to be reduced. The outer race of this bearing (or sometimes the inner race) is supported by means of another bearing or a row of balls or a set of rollers.

"It was our belief," Mr. Mims said. "that a compact, small cylinder con-

taining all the working parts of the oscillating system would have a ready market. The cylinder would be substituted for the conventional ball bearing and with the addition of two power leads would be driven by an external electronic oscillator. Such an electromagnetic device, with an order of magnitude reduction of ball bearing friction, would be useful in the instrument field in a wide variety of applications."

DESIGN PROBLEMS

Since the first target use for the bearing was in gyroscopes, the major problem was miniaturization. It was essential that electronic and mechanical engineers join forces in developing the most efficient oscillating means possible combined with a structure rigid enough to insure precision alignment of the oscillated bearing with the case. Preloaded support bearings were essential, but their torque had to be sufficiently low to allow oscillation with low power.

Because the inner ring of the "ball-bearing-whose-torque-is-reduced" (See Figure 2) had to be concentric with the housing O.D. within 0.0002 for most applications, considerable precision was required. The housing, special double-row support bearing, oscillating spindle and torque-reduced bearing all required concentricities in fractions of ten-thousandths because of tolerance build-up.

"When we decided to use a permanent magnet without brushes or slip rings as the oscillating mechanism," Mr. Mims said, "we found that design data was very sketchy. Although a reversing direct current had been planned, we discovered that low frequency alternating current would accomplish the purpose more easily."

In the first pole-piece and magnet designs it was difficult to avoid top-dead center positions. The pole piece has three fingers that alternate between all north and all south. The magnet polarity is staggered alternately north and south. When alternating current was applied to the coil the magnet oscillated. "We had thought that the amplitude would be just short of 60°," Mims said, "but actually it is necessary to overlap the pole pieces considerably to insure oscillation." The torsional resonance of the system was measured experimentally by driving the coil with a variable frequency oscillator and observing the amplitude of oscillation with a stroboscope. The resonant frequency is not very sharply tuned, varying from 10 to 13 cps in the larger Dynamic Bearing and from about 15 to 24 cps in the smaller unit.

Because it was expected that better integration of torques—lower residual torque—would be achieved by several revolutions of rotation, the designers tried at one stage to convert the electromagnetic structure into a motor by means of timed-switching, but the attempt was not very successful, nor did the torque appear to drop significantly.

Circle No. 65 on Inquiry Card

WORTH FILING

Tape Control System

12-page, 8½ by 11 inch two-color illustrated catalog describes a new tape control system for controlling the production of machined parts. Advantages and economies resulting from automating machine tools with this system are discussed and a complete description of how the system works is included. The tape control system is shown diagrammatically with photographs and line drawings from the numerical drawing stage to the control tape and the machine tool control unit.

A detailed description and drawings show how the control tape is prepared from a numerical drawing, a process sheet and a process tape, and how the machine control unit uses the information on the control tape to produce a part. Other features discussed are a typical machine and how it can be modified for the tape control system and specifications for tape preparation and machine control units.

Source: Bendix Aviation Corp.
Oak Park, Michigan
For your copy: Circle No. 120 on Inquiry Card

WORTH FILING

Tachometers

20-page bulletin describes a wide variety of hand and fixed types of speed measuring instruments including speed indicators; tachoscopes; single, triple, and five-range tachometers; hand tachometers; tachographs; and tachometer testers.

Source: James G. Biddle Co.
Philadelphia 7, Pa.
For your copy: Circle No. 112 on Inquiry Card

WORTH FILING

Radiating Systems and Components

32-page brochure contains detailed component data on antennas, antenna arrays, coaxial switches, power dividers, filters, diplexers and multiplexers, impedance matching devices, coaxial cable assemblies and complete antenna systems.

Source: Electronic Specialty Co.
Los Angeles 39, California
For your copy: Circle No. 108 on Inquiry Card.

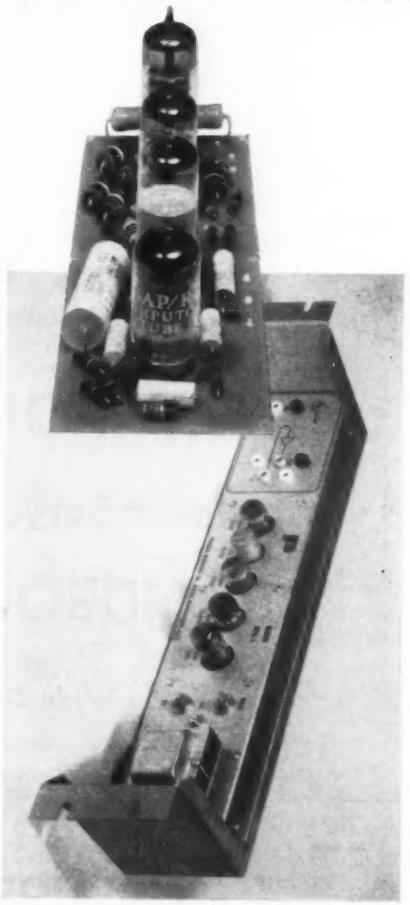
"We insist on the Philbrick amplifier for our new package" says Philbrick

HERE'S PHILBRICK ON PHILBRICK

"We use only the finest components in our products. That's why we insisted on Philbrick's new USA-3 Operational Amplifier as a sub-assembly for our new Analog Package, the UPA-2. We have found it (the USA-3) nifty and thrifty. We recommend it without reservation. And that goes for the UPA-2 — too."

PHILBRICK OPERATIONAL AMPLIFIER ... USA-3

More performance per dollar than any other amplifier. Highly reliable — no electrolytic capacitors or glow tubes. Designed to prevent self-destruction even when the output is grounded. Drift, noise, offset under 100 microvolts. Output is ± 116 VDC. Wide frequency range—DC to 100kc (attenuation less than 3db) when connected as a gain-of-ten amplifier. 7" x 2½" printed circuit board mounts by several convenient methods. **Price $95.**



PHILBRICK UTILITY PACKAGED AMPLIFIER ... UPA-2

Combines new level of flexibility and convenience. Performance characteristics same as the USA-3 amplifier, the heart of this package. Can drive 12,000 ohm load to 100 volts in either direction. Designed for 3½" rack mounting but can be used equally well as a bench amplifier, or plug-in assembly without modification. Use it for analog computing, measurement and control, continuous data reduction, and many other feedback operations. **Price $149.**

Write for technical literature and advice on your application.

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RESEARCHES, INC. *HUbbard 2-3225*
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THE ANALOG WAY IS THE MODEL WAY
CIRCLE 8 ON INQUIRY CARD

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advancement in instrument design

VERSATILE
MULTI-RANGE
METER TESTER
Model M-2

...POWER SUPPLY...LIMIT BRIDGE

Precise, self-contained unit for laboratory and production use. For DC instrument calibration from 25 ua full scale to 10 ma full scale, and 0-100 VDC; sensitivity and resistance measurement; DC current-voltage source; limit or bridge measurements from 0-5000 ohms. Regulated power supply. Stepless vacuum tube voltage control. Accuracy exceeds ¼% (current), ½ ohm or 1½% (resistance). For 115V, 60 cycle AC. Complete — needs no accessories. Bulletin on request. Marion Electrical Instrument Co., Manchester, N. H., U. S. A.

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U. S. Patent 2,740,093

marion
WHERE ELECTRONICS MEETS THE EYE
meters

CIRCLE NO. 9 ON INQUIRY CARD

NEXT MONTH

Instrument Servo Motor

HANDBOOK

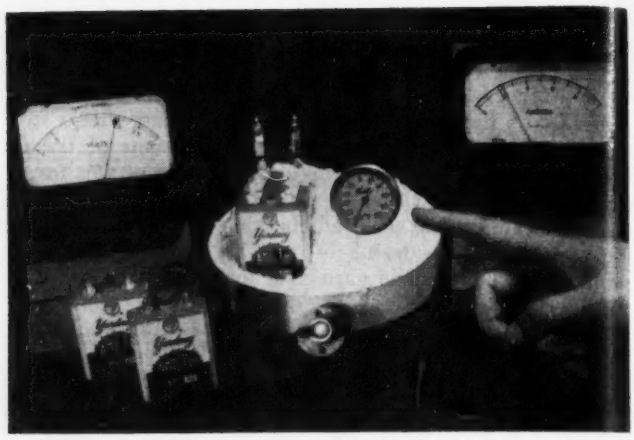
Industry-Wide Data

- Design
- Selection
- Application

Next Month ——— October 1958

in the pages of

ELECTROMECHANICAL
components & systems DESIGN



Arctic Primary Battery

Primary battery operates at −100°F and supplies appreciable currents for the first time at temperatures below −65°F. The non-aqueous cell operates over a wide range of temperatures—from 200°F down to −100°F and employs calcium for the negative plate, silver chloride for the positive plate, and an electrolyte with an acetonitrile solvent. There is no deterioration within the cell—it is hermetically sealed—and shelf life is expected to be infinite. It can be used in radio equipment and other devices in low temperature and high altitude regions. Batteries that can operate efficiently at −100°F will be of great use as power sources for unattended equipment, such as weather data instruments, that are located in extreme northern regions, and for aircraft electronic equipment in aircraft left exposed in the sub-zero temperatures that plague bases near the North and South poles. Yardney Electric Corp., New York, N.Y.

Circle No. 209 on Inquiry Card

New Regulator Has Magnetic, Electric Amplifiers

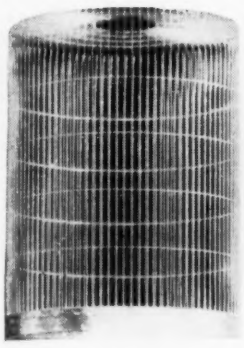
A new all-purpose two-stage regulator combines the best features of magnetic and electronic amplifiers and is used on adjustable-voltage d-c drives and other applications for voltage and current regulation in speed, tension, position and similar systems. Inputs are electrically isolated by a magnetic amplifier control input stage. A unique "grid switching" circuit controls the output rectifiers in the grid-controlled rectifier power output stage.

The basic regulator is manufactured as a compact and complete unit. Each of the four principal components; exciter unit (power), grid switching unit (control), reference unit and time delay unit are unitized and potted in individual steel drawn enclosures. Isolation of trouble, replacement, or modification can be quickly accomplished.

The magnetic-amplifier control stage provides multiple electrically-isolated inputs at low power and impedance levels in a completely static unit. The power output stage utilizing a single pair of gas-filled rectifier tubes provides high power output with fast response and inversion ability. This combination allows simplicity and flexibility in regulating system circuit design.

The regulator is available in three sizes: 5 amp maximum, 12.8 amp maximum and 36 amp maximum with intermediate ratings available. A-C supply is 220/440/550 volt, single phase, 60 cycle. A modification for 50 cycles is available. Standard modifications to provide timed rate response, current limit control and dual regulation are also provided. Clark Controller Co., Cleveland, Ohio.

Circle No. 104 on Inquiry Card.



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FOR VACUUM TUBE GRIDS

PLATINUM CLAD TUNGSTEN WIRE . . . Because of its superior physical properties at elevated temperatures, tungsten provides the more rigid, refractory core material required by high power tubes; it also exhibits lower interaction with platinum. Unlike molybdenum, platinum clad tungsten is readily hot stretched to take a permanent setting and lends itself to fabrication into grids employing conventional fixtures and spot welding procedures. Available in diameters from .001" and up.

Baker Platinum Division, 113 Astor Street, Newark, N. J.

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FOR UNVARYING PERFORMANCE

PRECIOUS METAL CONTACTS for long operating life and unvarying performance. Available in pure or alloyed forms of Silver, Platinum, Palladium, and Gold. These contacts provide extremely high resistance to atmospheric corrosion, deformation, arc erosion, sticking and metal transfer. They are supplied as wire, rod, sheet, and as fabricated forms.

Baker Contact Division, 207 Grant Avenue, East Newark, Harrison P. O., N. J.

FOR MORE INFORMATION ON CONTACTS CIRCLE 30 ON INQUIRY CARD

CHEMICAL DIVISION

FOR CORROSION-RESISTANT SURFACES

RHODIUM PLATING . . . an economical, hard, white, corrosion-resistant surface. Extremely well-suited for many electrical and electronic applications. Resistant to corrosive atmospheres, oxidation, arc erosion. Reduces wear on moving surfaces, assures low noise level for moving contacts, no oxide rectification, low and stable contact resistance. Ideal when a low-resistance, long wearing, oxide-free contact is required.

Chemical Division, 113 Astor Street, Newark 2, N. J.

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ENGELHARD INDUSTRIES, INC.

113 ASTOR STREET
NEWARK 2, NEW JERSEY

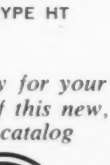
ESCO ROTARY SWITCH CATALOG

Includes detailed engineering data, electrical ratings, dimensioned drawings of switches and knobs, cutaway and exploded views

A deviation from one of these standard assemblies will give you a special switch at standard switch cost.

The 20-page catalog includes these standard multipole switches:

TYPE P


TYPE A

TYPE HT

- **Type P** — multisection, up to 4 positions, snap action, rating 10 amp. 125 v. a-c, 5 amp. 125 v. d-c, 30, 60, 100, 200 amp. 500 v. a-c/250 v. d-c. Can be assembled per MIL-S-15291.
- **Type JR** — up to 8 positions, 30 sections maximum, detent action, rating 10 amp. 125 v. a-c, 5 amp. 125 v. d-c.
- **Type A** — up to 8 positions, 7 sections maximum, detent mechanism, rating 5 amp. 125 v. a-c/30 v. d-c.
- **Type AF** — up to 8 positions, 6 sections maximum, detent action, resistive rating 5 amp. 28 v. d-c or 115 v. 400 cps, per MIL-S-6807.
- **Type HT** — up to 16 positions, 10 sections maximum, dentent action, rating 5 amp. 125 v. a-c.
- **Navy switches** — to MIL-S-15291 and Bureau of Ships drawings 9000-S6202-73075, 73826, 73827, 73295, 74422, and others.
- **Trigger switch** — heavy-duty momentary contact, with 4-conductor cable; meets Navy specs.

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ELECTRO SWITCH CORPORATION

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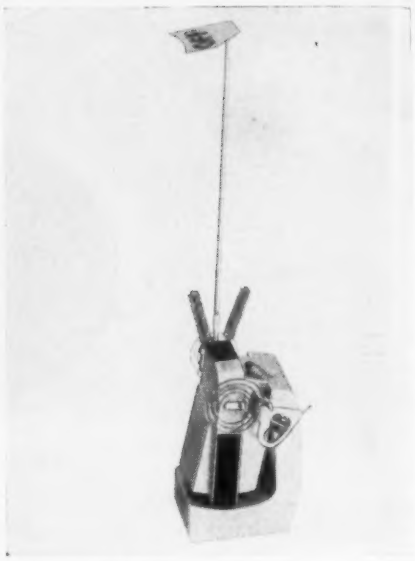
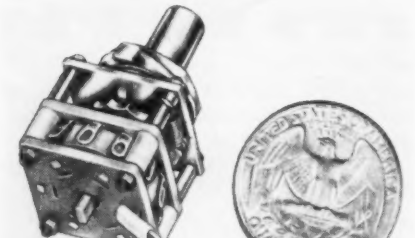


End-pivoted Moving Coil Mechanism

A small, lightweight moving coil indicator has been developed for use with aircraft instruments requiring flag or alarm indications with short deflection angles. The indicator uses an end-pivoted mechanism which has internal pivots, high torque and a shielded magnet. Small size and light weight (½ oz.) permit flexibility in mounting location and the internal magnet design makes compass influence negligible. Marion Electrical Instrument Company, Manchester, N. H.

Circle No. 99 on Inquiry Card



Stable Hi-Temp Resistors

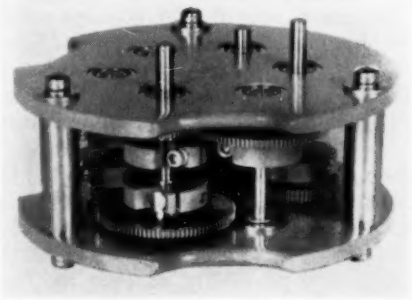
Two new high stability resistors for missile, aircraft and other applications involving high ambient temperatures maintain their full rating up to 200° and 275°C, respectively, derate to 0 at 325°C, and meet all environmental requirements of Specification MIL-R-10509B. In addition they are unaffected by severe ambient conditions such as moisture, dust, salt spray, etc.

Resistance of Type HT-1 is from 200 ohms to 360K ohms with a maximum voltage of 600 volts; resistance of Type HT-2 is 200 ohms to 1 meg with a maximum voltage of 1500 volts. The Victoreen Instrument Co., Components Div., Cleveland 3, Ohio.

Circle No. 75 on Inquiry Card

Cavity Tuning Precision Potentiometer

In modern communications practice, remotely controlled cavity (or capacitor) positioning is often required to tune a receiver or an oscillator to a specific frequency. Extreme accuracy is required because of the narrow bandwidth of receivers and the close frequency spacing of adjacent channels. The problem is further complicated by the non-linearity of the cavity frequency versus control position characteristic. This is normally a hyperbolic function with minor variations due to idiosyncracies of specific cavity types. In the case of a servo-positioned cavity, it is possible to linearize the frequency versus command voltage function of the servoed cavity by the use of a suitably non-linear follow-up potentiometer.



Analogue Controls' cavity tuning potentiometers embody the required linearizing function to an accuracy which permits cavity tuning to within 0.025 percent of total frequency variation. Depending upon cavity range and receiver bandwidth, this accuracy is frequently sufficient to eliminate the requirement for lock-in circuitry.

Available for a number of standard cavities, with little difficulty the technique can be extended to other similar requirements. Mechanical and detail specifications are per Analogue Model F1810 (2″—10-turn, synchromount). Analogue Controls, Inc., Mineola, N.Y.

Circle No. 82 on Inquiry Card

Higher Power Subminiature Resistors

An increase in wattage ratings of sub miniature precision wire wound resistors has been made possible by a newly developed insulating compound that is applied to the winding and is also used to encapsulate the finished product. Typical of the higher wattage ratings available in the new Min-istor series is the subminiature axial style measuring 3/16″ diameter and ½″ in length, now rated at 0.5 watts at ambients up to 105°C with a maximum 400K value. Tolerances as low as 0.05% can be specified. Eastern Precision Resistor Corp., Brooklyn, N.Y.

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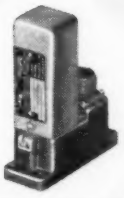
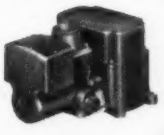
SPECIAL ACTUATORS

GENEVA-LOC* ACTUATORS

NAVIGATION LIGHT FLASHERS



MINIATURE ROTARY ACTUATOR



DEICER TIMERS

RESET SEQUENCING TIMERS

RELIABLE ELECTRO-MECHANICS BY Bendix-Pacific

Whether you want actuation for throttle adjustment, propeller synchronization, sequence timing or high vibration valve control, Bendix-Pacific Electro-Mechanical products offer the reliability so essential to today's aircraft, engine and missile projects.

Quality and reliability are vital to proper functioning, and low cost actuating systems no longer can be measured by the initial purchase price alone. Maintenance expense and dependable service life are equally important to true economy.

The quality built into Bendix-Pacific Electro-Mechanical products is illustrated by the fact... that only the famous Geneva-Loc* Actuators give positive locked mechanical positioning . . . and that 65% of Bendix-Pacific's current Electro-Mechanical production is scheduled for jet engines, turbo propellers, I.C.B.M.'s and drones where reliability is essential and environment adverse.

For maximum reliability and overall economy, consult your Bendix-Pacific sales engineer prior to finalization of your specification requirements.

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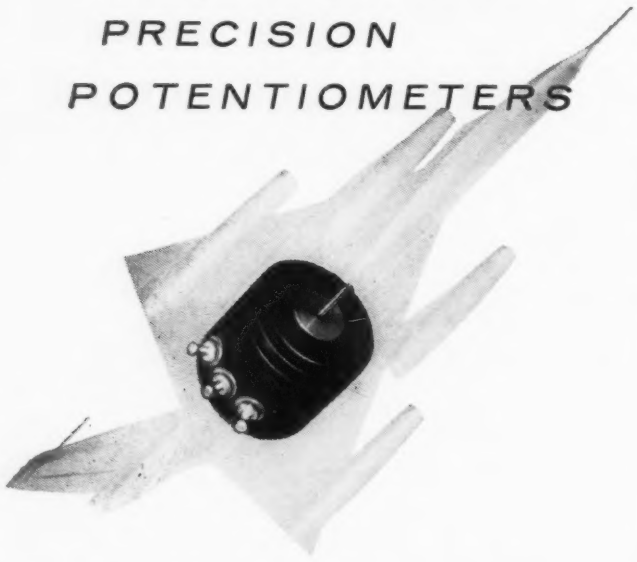
JEWEL BEARINGS
help to produce
PRECISION
POTENTIOMETERS



Waters LO-TORK Potentiometers with Bird Jewel Bearings are used on U.S. Air Force Supersonic bombers.

Here's how Bird Sapphire Jewel Bearings helped a prominent manufacturer of electrical instruments to make a major product advance.

Waters Manufacturing, Inc., manufacturers of precision potentiometers, were asked to design a miniature potentiometer with minimum torque and reliable operation when operated in a contaminated fuel mixture. The result was the new Waters LLT ⅜ LO-TORK potentiometer with jewel bearings — an entirely new concept in miniature potentiometers.

Bird Sapphire Jewel Bearings are specified in the new Waters LO-TORK Potentiometers because they provide higher accuracy and longer instrument life. Waters LO-TORK Potentiometers with Bird Sapphire Jewel Bearings stand up under even the most rugged accelerated corrosion tests conducted by the Armed Forces. In fact, Waters LLT ⅜ potentiometers are now being used in fuel flow meters where they must withstand the rigors of jet fuel.

Bird Precision Jewel Bearings have been used by the foremost manufacturers of electrical, aircraft and timing instruments and recorders. They are available in a wide range of standard types, sizes and complete assemblies — or custom-built to your specifications.

If your product design calls for jewel bearings, our engineering staff is at your service. A request on your letterhead for Bulletin 100-9 will receive our prompt attention.

Richard H. Bird & Co., Inc.

1 Spruce Street, Waltham 54, Mass.

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JEWEL MOUNTING & ASSEMBLY • SAPPHIRE STYLII

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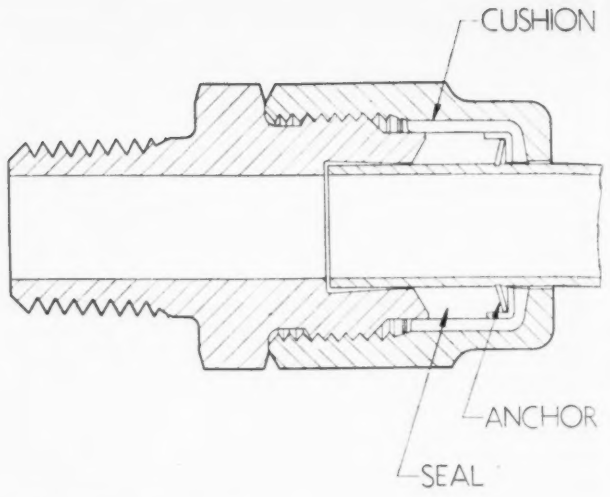

Flareless Tube Fitting

A flareless tube fitting absorbs impulse shocks and vibration, thus eliminating one of the major causes of tube and fitting failure. The fitting utilizes a new design concept which provides maximum tube movement in a leak-proof joint, a necessity in today's hydraulic and pneumatic systems. It meets or exceeds flareless tube fitting standards of the J.I.C. and because it is simple and easy to install, important cost savings result.

Tradenamed Rubbernek, it can be connected and disconnected repeatedly making a perfect leak-proof joint every time. For installation, no flaring, pre-setting, welding, soldering or tube preparation is necessary. A built in "positive stop" precludes the possibility of over torquing yet assures the user of a properly tightened fitting without the use of special tools or techniques. The entire fitting is furnished as a complete assembly, so installation is easy and foolproof.

Rubbernek fittings make it easy to reliably connect tubes misaligned because of cumulative manufacturing variables. This patented fitting has undergone severe and rigorous tests which prove that it holds pressures beyond the burst strength of the tubing itself. Chicago Forging & Manufacturing Company, Chicago 14, Illinois.

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WORTH FILING

Air Valve Catalog

108-page general catalog believed to be one of the most detailed and informative ever offered in the valve field is "departmentalized" into four convenient sections: 4-way valves and manifolds; 2-and 3-way line valves; manual valves and manifolds; pilot and special valves. For quick reference each of these sections is preceded by an identity tabbed index page. All of the information on each valve which a designer, engineer, master mechanic or purchasing agent might require, is presented in a concise fully illustrated fashion. In addition to the usual application and operational data, specifications, dimensional drawings, parts lists, etc., Numatics has included, for extra convenience, handy valve selection charts and J.I.C. symbol diagrams. Special catalog features include a Valve feature comparison chart, special circuit applications table and "how-to-do-it" data on manifold mounting patterns and vacuum valve applications.

Source: Numatics, Inc.
Highland, Mich.

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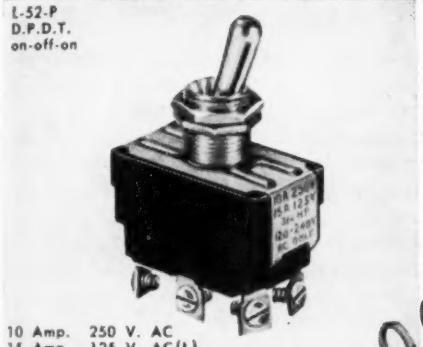
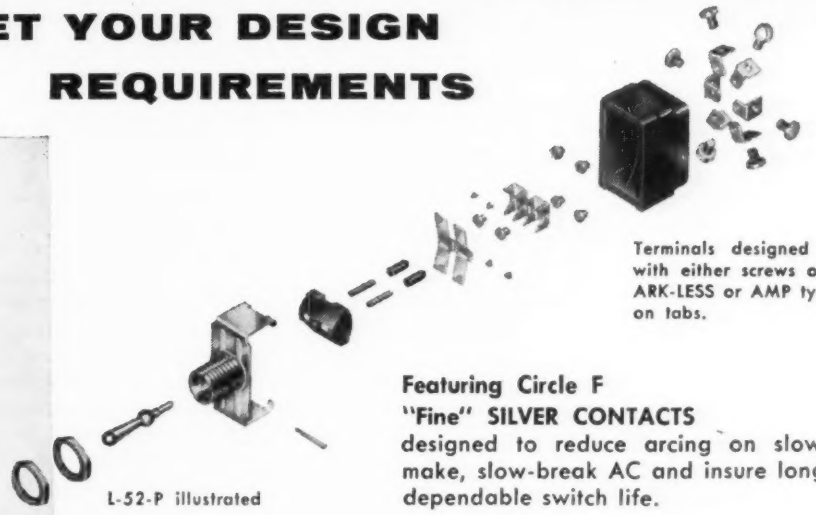
PRECISION-ENGINEERED CONTROL SWITCHES TO MEET YOUR DESIGN REQUIREMENTS

L-52-P
D.P.D.T.
on-off-on



10 Amp. 250 V. AC
15 Amp. 125 V. AC(L)
¾ H.P. 120-240 V. AC



Terminals designed for use with either screws or female ARK-LESS or AMP type push-on tabs.

L-52-P illustrated

Featuring Circle F "Fine" SILVER CONTACTS designed to reduce arcing on slow-make, slow-break AC and insure long, dependable switch life.

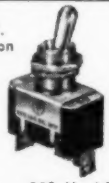
L-40-A
S.P.S.T.
on-off

10 Amp. 250 V. AC
15 Amp. 125 V. AC(L)
¾ H.P. 120-240 V. AC

1887-LP
S.P.S.T.
on-off

3A - 125 V (T)
6A - 125 V
3A - 250 V

L-42-E
S.P.D.T.
on-off-on



10 Amp. 250 V. AC
15 Amp. 125 V. AC(L)
¾ H.P. 120-240 V. AC

2230
S.P.S.T.
on-off

10 Amp. 250 V. AC
15 Amp. 125 V. AC
¾ H.P. 120 V. AC
1½ H.P. 240 V. AC

No. 438-L
ACTUAL SIZE
15 Amp - 125 Volt

Now Circle F offers new economies to design engineers through the use of standard medium-duty, one-hole switches, *available for modification to meet particular specifications.*

New standards of quality-controlled manufacture permit these precision-engineered switches to be *"custom-made"* and delivered in production quantities in *less time* and *at the lowest possible cost.*

Write Department M for full information and engineering assistance.

FLUSH MOUNTING, SNAP-IN CONVENIENCE OUTLETS AND SWITCHES

M-2230-H illustrated

FAST, EASY SPRING CLIP INSTALLATION
COMPACTLY DESIGNED — COMPETITIVELY PRICED

Ideally-suited for bathroom fixtures, medicine cabinets, ranges, and other electrical appliances. Snap-in Convenience Outlets and Medium-duty Switches are rated 15 amp, 125 V. Clip will accommodate wall thicknesses of .025" to .095".

Listed by Underwriter's Laboratories, Inc. and certified by Canadian Standards Association

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Box 591, Trenton, N. J.

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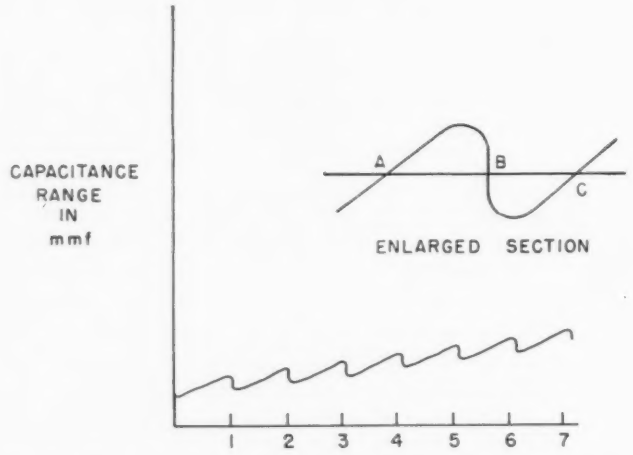


Fig 1—Typical performance curve of a conventional piston capacitor showing effects of runout. When an engineer gets a piston capacitor set at the value he wants, he doesn't know whether he is at point a, b, or c on the curve. If he is at point b and attempts to increase the capacitance in the usual manner the capacitance drops. On the other hand, if he's at point c and attempts to decrease capacitance it drops at first and then starts up again. The operator is blind as to where he is on the range of capacitance.

MINIATURE GLASS TRIMMER CAPACITOR

"Full Floating" Piston Design Assures Accurate Alignment

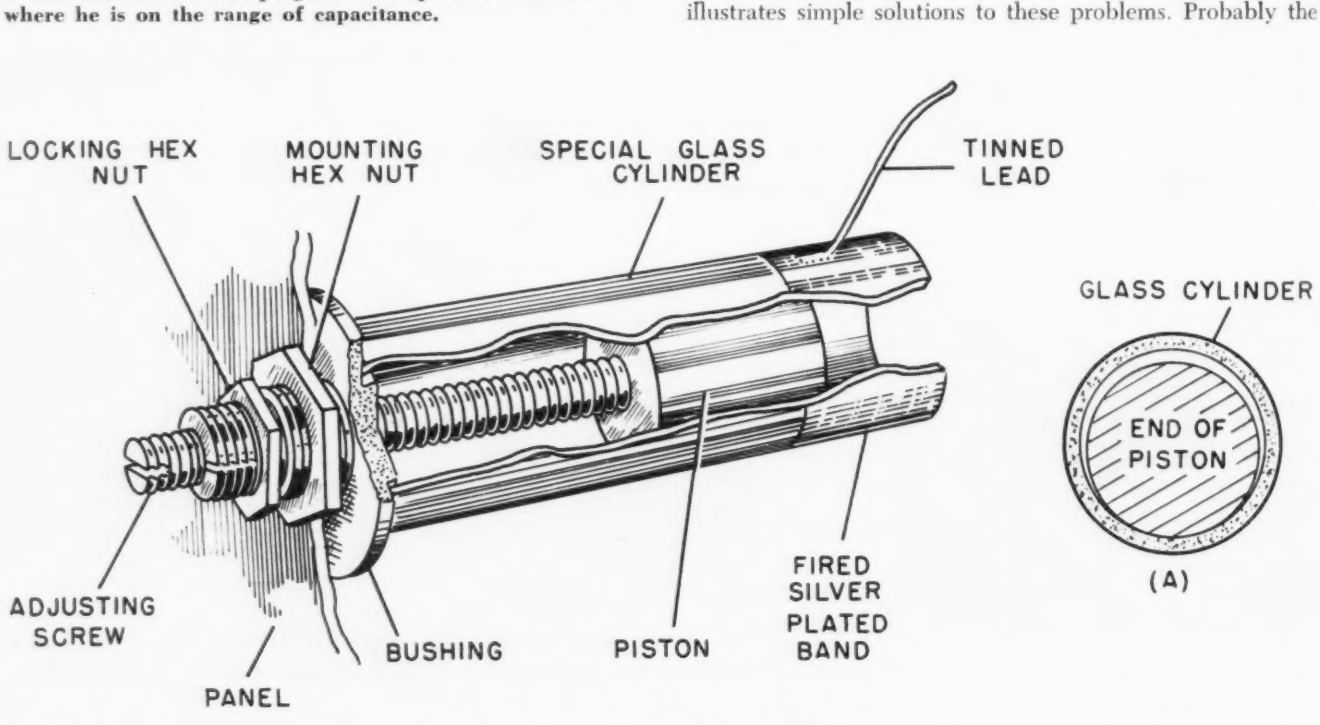
By applying good mechanical engineering in electromechanical design, Atlas E E Corporation of Woburn, Massachusetts solved three basic problems in trimmer capacitors.

- The major poblem in conventional units is runout (misalignment), which results in "loopbacks" in the curve of capacitance plotted against number of turns of the adjusting screw.
- The second problem is change in capacitance under shock or vibration, or when the locking nut on the adjusting screw is tightened.
- The third problem is excessive weight and space.

Figure 2 showing a cutaway view of a typical standard-glass piston-type trimming capacitor will illustrate these problems.

Great strides have been made in reducing runout and effects of shock and vibration in conventional designs by precision machining and assembly methods. They have not been eliminated completely, however, and the weight problem remains.

The cutaway perspective sketch of the new Atlas trimmer illustrates simple solutions to these problems. Probably the



Typical Conventional Trimmer Capacitor. Capacitance is varied by moving the piston back and forth inside the glass cylinder walls by means of the adjusting screw which is supported solely by the bushing. The further the piston is under the fired silver-plated band, the greater the capacitance; the nearer it is to the bushing, the lower the capacitance. To get the minimum capacitance there should be roughly a 1/32-inch air space between the end of the piston and the fired silver-plated band. The capacitor is mounted with the bushing sticking through the panel and held tightly in place with a hex nut. Left end of the bushing near the locking hex nut is a split section. As the locking hex nut is turned on tighter, it locks the adjusting screw into position with the result that adjusting screw and piston are rigidly connected and the piston is supported entirely through the adjusting screw, which in turn is supported by the bushing. When the piston is all the way out, giving the greatest capacitance, there is quite a bit of leverage on the bushing. Unless the piston and the inside of the glass are very carefully ground and unless the threads in both the bushing and the adjusting screw are very accurately machined, the piston can take an eccentric position with respect to the glass cylinder at full capacitance, as illustrated, but exaggerated, in Fig 2A. This is the problem of mechanical runout and the cause of the loopback curve in Fig 1. Shock or vibration tend to move the end of the piston around inside the glass cylinder changing the capacitance. Tightening the hex nut to the panel or adjusting the locking hex nut on the bushing could move the adjusting screw after it had been carefully adjusted. Inertia of the solid piston contributes to inaccuracy especially when the piston is fully extended.

most noticeable thing about the design is that the adjusting screw is not nearly as long, the bushing is very short and simple, and that only a single locking nut is needed to hold the unit to the panel and to lock the adjusting screw in place.

The piston is a formed, expanding, metallic core of 0.010-inch brass (invar or nickel alloy if required) designed to expand against the inner wall of the glass tube. It connects to the adjusting screw through a very simple type of universal joint that frees the piston from rotational motions of the screw. Mechanical alignment problems are negligible as a result of this full floating action of the expanding core piston. Because the expanding core is a formed metal piece, its inertia and consequent motion under vibration and shock are minimum. When the adjusting screw is fully in and the piston is extended for maximum capacitance, the relation of the expanding core piston to the fired silver-plated band remains the same regardless of vibration and shock.

Atlas doesn't have to grind the surface of the glass cylinder. Making it on a plus three thousandths minus one thousandth basis is adequate. Ordinary screw machine tolerances in the bushings are sufficient to make glass cylinder and bushing concentric when they are soldered together.

One side of the bushing is D shape to fit into a D shaped slot in the panel so that the bushings will not turn. A simple, inexpensive Tinnerman speed nut holds the unit tight to the panel. The nut can be locked in place to prevent it from turning, simply by putting a small hole in the panel so that the small notch on the nut will slip into the hole.

Once the expanding core trimmer has been set to a value it will not charge. A performance curve of the expanding core trimmer showing capacitance as a function of adjusting screw turns is a straight line without any wave forms whatsoever. Furthermore, the curve is exactly repeatable plotted in the reverse as well as the forward direction. This ability to retrace performance is not possible with a standard piston type unit.

Atlas President Allen Mowatt points out another and very practical advantage of this design. "The fact that Atlas doesn't have to be as precise in machining and assembling the parts means the trimmer can be produced very economically in large quantities." He contemplates making the trimmers in quartz as well as glass and using an invar expanding core, if temperature and other requirements warrant. All the brass parts are silver plated to protect them from salt spray corrosion. Various types of mountings will be available; probably one of the first will provide rigid tinned leads for printed circuit applications.

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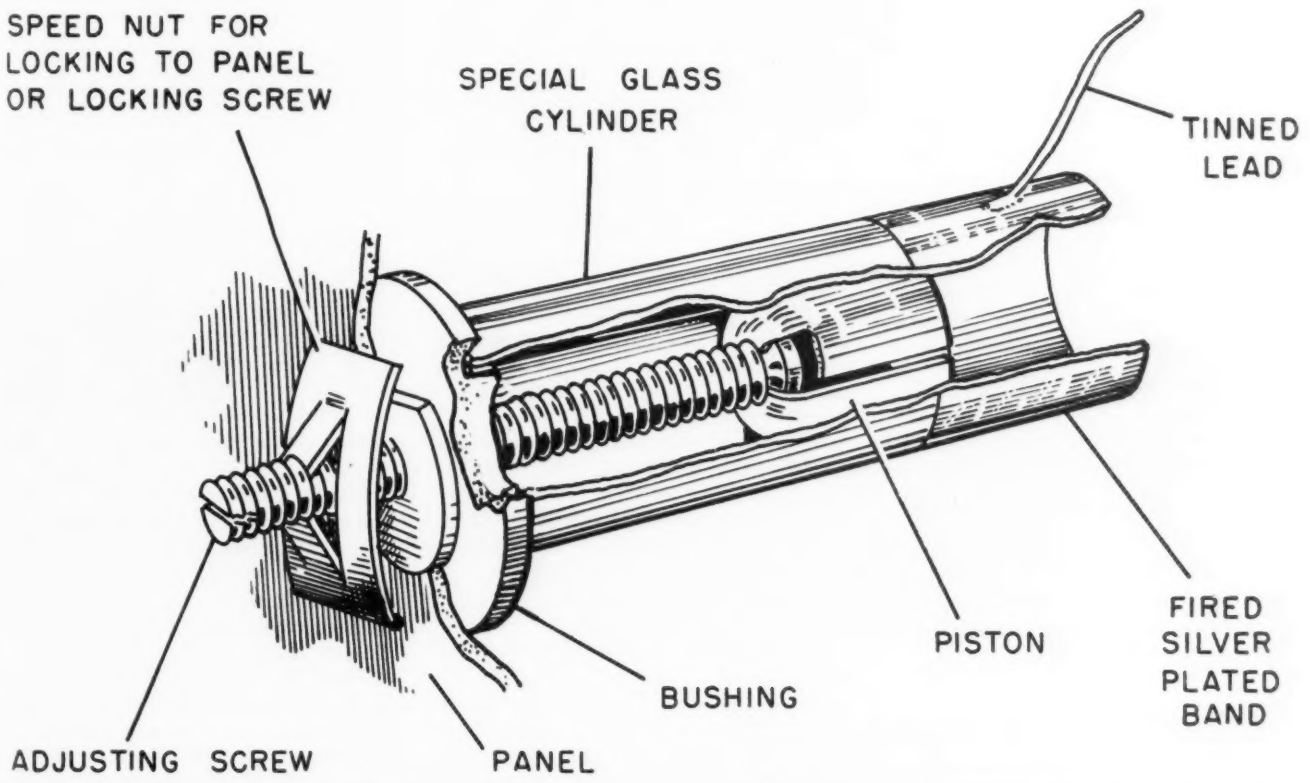

New Expanding Core Trimmer Capacitor. Atlas designers eliminated runout by using an expanding core piston that does not rigidly connect to the adjusting screw. Connected to the screw by a universal joint, the piston expands against the inside diameter of the glass and rides without turning. This configuration maintains concentricity between the capacitor elements, thereby eliminating loopbacks in the performance curves. The fact that the core presses against the inside of the glass prevents it from changing value under shock and vibration. Tightening the locking nut against the panel in no way affects the motion of the piston because it's not rigidly connected to the adjusting screw. Weight is reduced by using the formed metal core instead of a solid piston. Having a thin small bushing and eliminating one of the hex nuts reduces the length of the adjusting screw, making the overall unit smaller. The piston also can be smaller because an expanding core gives more capacitance for a given size than a solid-type piston does. Since the adjusting screw and piston are separately supported, stresses on the components are minute even under extreme vibration and shock.

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COLOR

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At long last you can now secure beautifully bright, gleaming colors from a simple LUSTER-ON chromate dip process for your zinc plated small parts.

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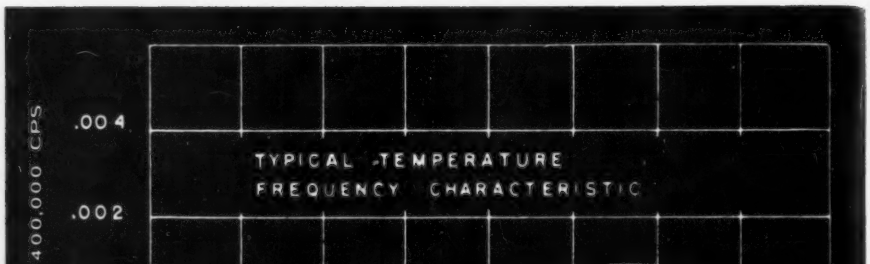
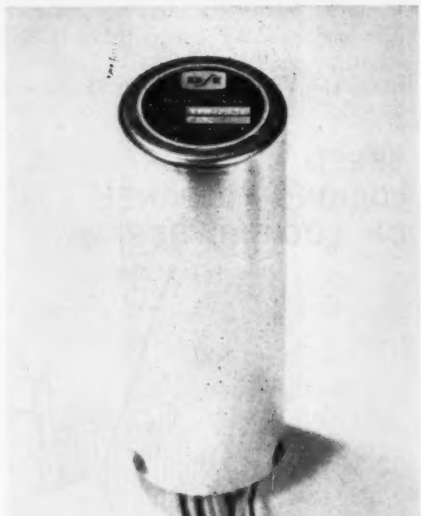


Secondary Frequency Standard



A secondary frequency standard which provides a stable 400 cycle frequency source for precision airborne and missile requirements was designed as the nucleus of a program timer built to "brain" the various functions of a 3-stage artificial satellite launching rocket from launching time until orbital free flight 200 to 400 miles or so above the earth is attained.

Patrick E. Lannan, Designers for Industry Vice President in charge of this project, pointed out that time accuracy is all important to a successful flight. "The biggest difference between this timing device and one used on, say the Viking rocket," he said, "is the extreme accuracy of timing required."

Using the completely transistorized secondary frequency standard, the timing device will withstand the heavy shock and vibration associated with missile flights. Located in the second stage of the 3-stage rocket, the timer "programs" the various functions until the third stage is launched.

The Secondary Frequency Standard comprises a crystal controlled oscillator, six binary count down stages and a tuned power output stage. Providing a highly reliable frequency source in a small package, the crystal is mounted in a rugged holder and the printed circuit assembly is completely dip potted to permit high acceleration shock and vibration. All transistors are made from silicon. Low thermal coefficient components are used to insure reliability and stability without the use of a thermostatically controlled oven.

The unit has a locking range from 15 to 40 volts, an output frequency of 400 cps and a frequency stability of +0.002%. Output power is 50 milliwatts. The frequency standard is 4½" long and 1¾" in diameter and weighs only 11 ounces. Designers for Industry, Cleveland 9, Ohio.

Circle No. 96 on Inquiry Card

Control Reactors

Control reactors for magnetic amplifiers cover the sensitivity range from 1.5 to 15 amperturns (15 to 45 watts) in four series. There are 48 standard units in all and the military versions meet or surpass all MIL-T-27A specs. Four standard windings are provided and units can be ordered with any number of windings up to eight. Chicago Magnetic Control, Division of Chicago Electronic Engineering Co.

Circle No. 103 on Inquiry Card.

Modular Electronic Pre-Set Counters

A new series of modular pre-set electronic counters is available in every size from 2 to 6 digits in the standard line. Each standard instrument consists of one pluggable amplifier and control unit plus any combination of pluggable 2 and 3 decade modules.

Designed for industrial counting, sorting, batching, winding, packaging and other control functions, the Erie Model 320 counter will count at a maximum rate of 5000 counts per second, accepting any standard waveform. Either a-c or d-c coupled inputs may be selected from front panel. Input pulse widths as short as 1 microsecond will provide adequate drive. A photocell input is provided.

Depending upon the number of decades used, the operator may set in any number from 1 to 999,999 (6 decades) by selecting the decade switches to the desired number. The unit will count until the total is reached, at which time the unit provides an output pulse.

The company states that the output circuity provides a wide range of control functions. In the "Pulse Only" position, the unit delivers a large pulse of voltage to the output load at the end of each pre-set counting interval, then automatically resets itself and resumes counting.

With the function switch set in the "Relay" position, a control relay closes when the desired count is reached. Duration of the relay closure, variable up to 5 seconds, is determined by a "Hold Time" control on the panel. A "Relay Latch" position provides a third method of control. Upon reaching the desired count the control relay closes and is held indefinitely. A "Reset" button on the panel releases the relay, clearing the system for the next counting group.

To facilitate spot functional tests, a 60 cycle "Test" position is provided on the input selector switch.

The counter is also available as a dual preset counter, having the same features previously described. For dual preset operation two separate numbers of up to 6 digits (on standard models) can be selected from the front panel. Upon reaching the smaller number, relay "A" closes. When the larger number is reached relay "B" will close. This dual function readily permits a programmed two step operation for machine control.

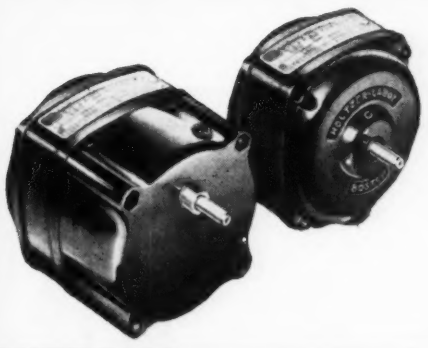
The company stated that optional accessories for the counters include an a-c amplifier to increase sensitivity from 1 volt to 25 millivolts and a 5-digit batching register. Erie Resistor Corp., Hawthorne, Calif.

Circle No. 81 on Inquiry Card

New Designs in Motors from HOLTZER-CABOT

VARIABLE SPEED SUB-FRACTIONAL DC MOTOR

This new motor—Model RBD-25—is available in two standard units: RBD-2505 with a rating of 0.5 oz. inches; and RBD-2510, rating 01.0 oz. inches. Both operate at speeds up to 1800 RPM with input of 24 to 115 V. D. C. This is a shunt wound motor and speed can be varied by changing armature voltage.



2-SPEED REVERSIBLE SUB-FRACTIONAL AC MOTOR

Model RBC-2514. Available with basic speeds of 1800 RPM and 3600 RPM and with standard gear reductions from 3:1 to 3600:1. Basic torque ratings for continuous duty at 115 volts, 60-cycles; 3600 RPM synchronous range from 0.15 to 0.5 oz.inches.

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Designed primarily for research laboratories and engineering departments, this kit makes it possible to determine the proper servo, torque or synchronous motor required for instrumentation and automation applications. Eliminates the need for purchasing sample motors for testing. Contains all the necessary motors and components to assemble—with bench tools only—32 different motors.

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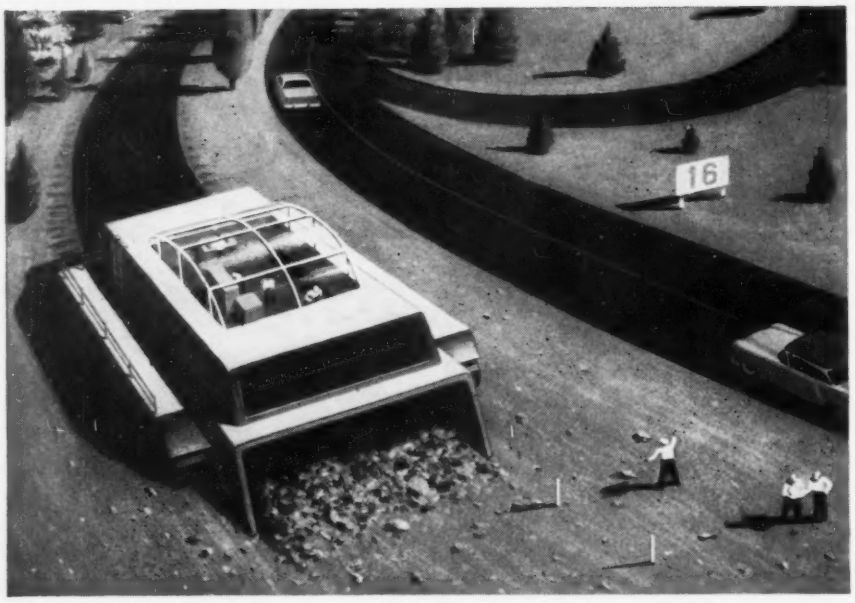

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In pencils, of course, that means Mars, long the standard of professionals. Some outstanding new products have recently been added to the famous line of Mars-Technico push-button holders and leads, Lumograph pencils, and Tradition-Aquarell painting pencils. These include the Mars Pocket-Technico for field use; the efficient Mars lead sharpener and "Draftsman" pencil sharpener with the adjustable point-length feature; Mars Lumochrom, the color-drafting pencils and leads that make color-coding possible; the new Mars Non-Print pencils and leads that "drop out" your notes and sketches when drawings are reproduced.

The 2886 Mars-Lumograph drawing pencil, 19 degrees, EXEXB to 9H. The 1001 Mars-Technico push-button lead holder. 1904 Mars-Lumograph imported leads, 18 degrees, EXB to 9H. Mars-Lumochrom color-drafting pencil, 24 colors.

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FOR MORE INFORMATION CIRCLE 16 ON INQUIRY CARD

SYSTEMS DESIGN

XENON ELECTRONIC FLASH SENSITOMETER

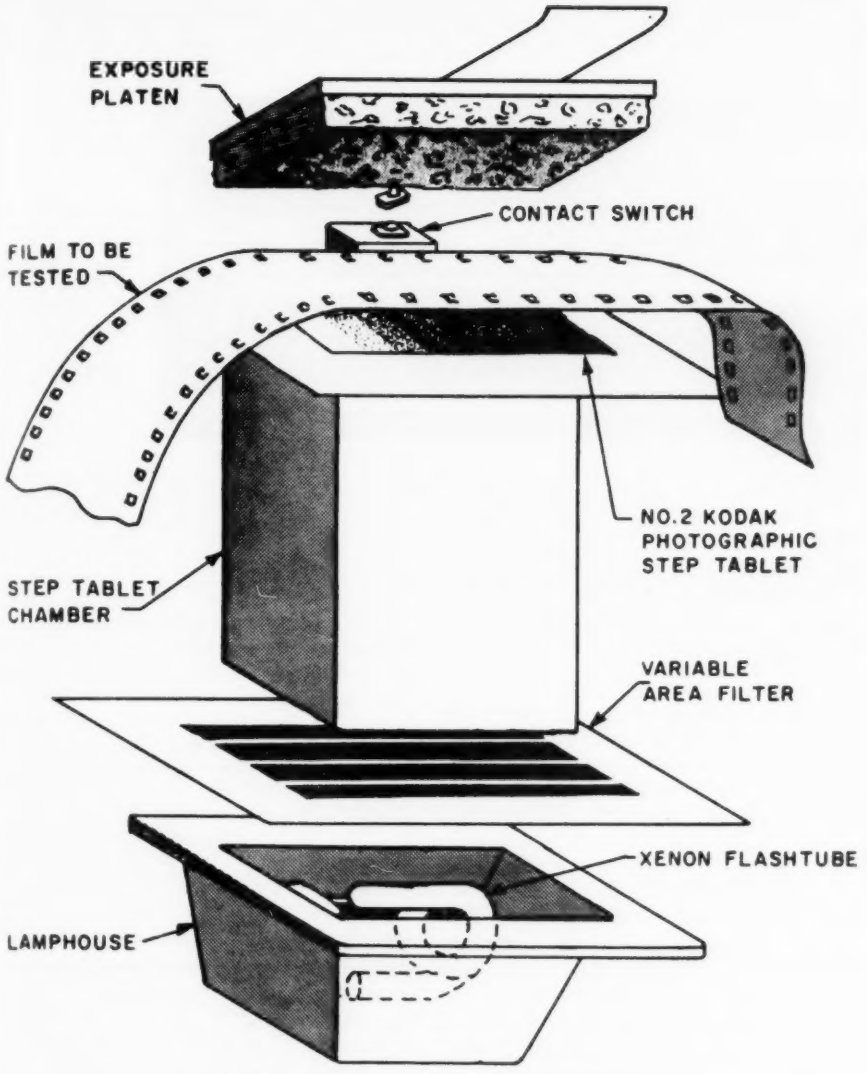
Use of a xenon flash tube and a new design concept that eliminates all dials and meters have cut the cumbersome, complex, and often room-sized sensitometer down to a simple, rugged unit of cash-register size.

The sensitometer has been a part of professional photography for many years. Traditionally, it has been a piece of equipment so cumbersome and complex that it has had no practical application for darkroom technicians. Its use has been limited largely to the darkrooms and laboratories of the photographic supply manufacturers and those organizations engaged in photographic work of a highly advanced or technical nature.

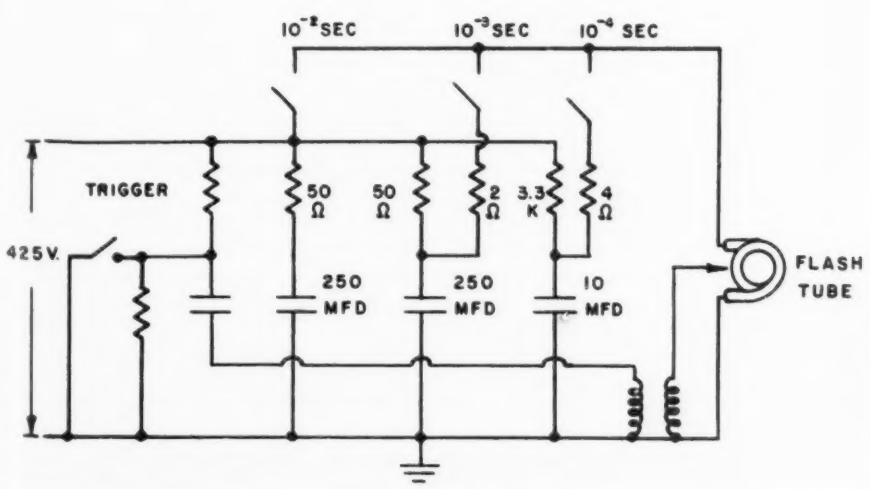
The Xenon Electronic Flash Sensitometer is a new approach to sensitometry. It is a small, and convenient instrument for the average photographic technician to use in his daily work. With it, he can quickly and accurately determine the exact sensitivity of films, paper, emulsions, and other light-sensitive materials. He can make revealing studies of short-exposure reciprocity failures, a perplexing subject, which has bothered the industry for several years. The instrument is effective for such routine tasks as checking on developer activity or of development techniques, contrast control, film-speed determination, and even color-filter selection for the balancing of color films.

BACKGROUND

Several years ago, when Edgerton, Germeshausen & Grier, Inc., took on the task of high-speed photography for the Atomic Energy Commission's nuclear weapons test program, they decided that processing of the photographic records was just as important as initial recording. The primary task was that of collecting data in the form of measurements made from photographically recorded images. Because both geometric and photometric measurements were required, it became obvious that precise control would have to be maintained over both the recording and the processing phase. The extent of the controls would be dictated by the degree of accuracy re-



Schematic presentation of the sensitometer.



Typical Circuit Diagram of an EG&G Mark VI Xenon Electronic Flash-sensitometer. A built in voltage-stabilizer transformer insures constant output with as much as ± 20 percent line-voltage fluctuation.

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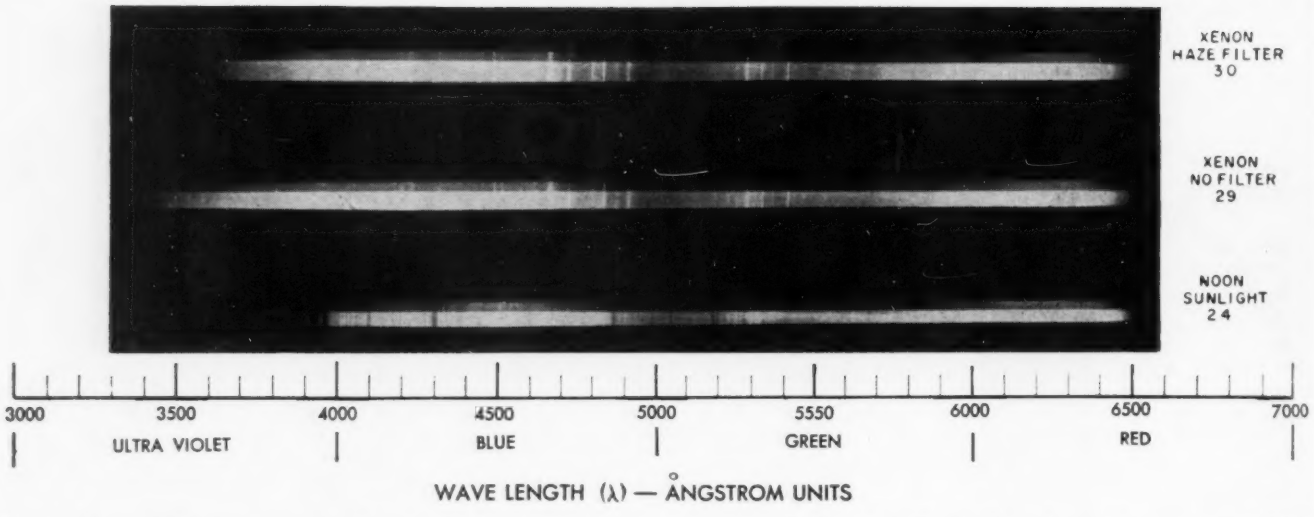


Step-wedge spectrograms on panchromatic film of an electronic flash tube filled with various rare gases relative to noon sunlight. The illustration shows that a xenon-filled tube is a close approximation to sunlight.

quired of the overall task.

EG&G began a study to determine the potentialities of available photographic emulsions. They decided at the start that a sensitometer would be a basic instrument in that study and that most of the exposures involved would be outside the normal range and well into the reciprocity-failure regions of high-intensity, short-time durations.

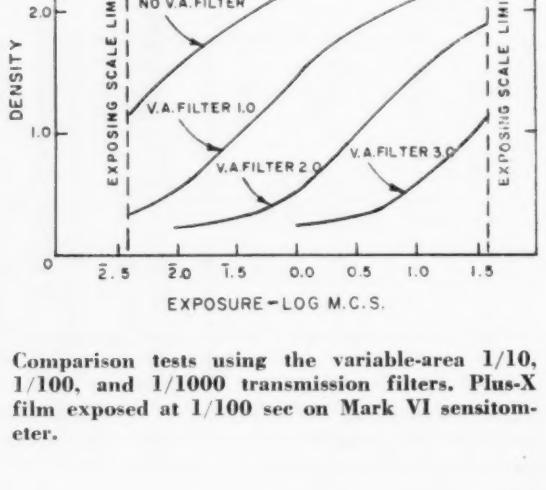
Because the primary photographic work of EG&G is in the range of high speed photography, typical exposure durations are too short to be within the limit of commercially available sensitometers. It was necessary, then, to design a sensitometer to meet specific requirements. Since the company is a pioneer in the development of electronic flash equipment, they decided to use such a light source for the illumination system.

The resultant instrument had certain inherent advantages over conventional sensitometers. Its features were described in a paper read before the Society of Motion Picture and Television Engineers which stated that the amount of light produced by each flash is virtually independent of the voltage input. If the supply voltage changes, the effective color temperature of the light output does not change. The xenon flash tube offers excellent color quality, but more significantly, it maintains a consistency in both the quantity and quality of its light output over an extremely extended life. More than 200,000 flashes can be obtained from the xenon tube, equivalent to a lifetime of normal use in a busy studio.

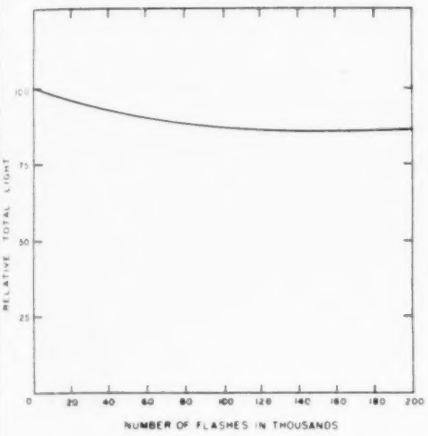
THE DESIGN

The flashtube is mounted in a housing which is open at the top. Directly above is a variable area filter. Purpose of the filter is to regulate the total amount of light falling on the photographic material being tested. Standard neutral-density filters may be used if desired, but generally the set of variable-area filters provided with the equipment gives better results. To alter the spectral quality of the light being emitted, a color filter may be inserted along with the variable-area filter. Immediately above the filter is a chamber, the top of which contains a No. 2 Kodak photographic 21-step tablet which serves as the exposure scale. The purpose of separating this exposing scale a given distance from the

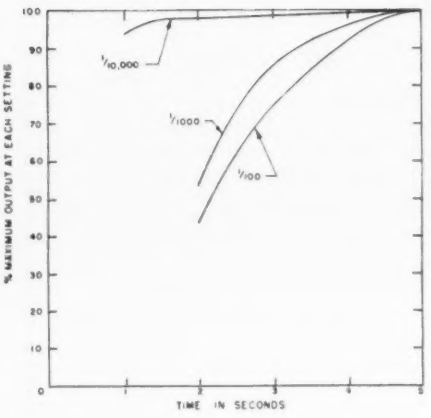
General Radio Integrating Exposure Meter being used to measure sensitometer light output.



Comparison tests using the variable-area 1/10, 1/100, and 1/1000 transmission filters. Plus-X film exposed at 1/100 sec on Mark VI sensitometer.



Light output as a function of tube life. Starting with a new tube, the total light value is set at 100 on the y-axis. A loss of light, amounting to approximately 10 percent takes place at a gradually decreasing rate over the first 40,000 flashes. From then on, the light loss becomes less uniform amounting to only a few percent up to some 200,000 flashes. Thus, the total loss of light over 200,000 flashes amounts to approximately 15 percent.



Charging time as a function of maximum light output for each of the three circuit conditions of the sensitometer. With only a 2-sec waiting time, both the 0.01-sec and the .001-sec pulses will produce approximately half the total light. After 5 sec, all three of the circuits will be fully charged and the light output from flash to flash will be repeatable within a few percent. For consistency it is therefore necessary to wait at least 5 sec before making another exposure. In actual practice it is difficult to make exposures faster than one every 5 sec.

filters and light source is to ensure even illumination in the exposure plane.

The film or other light-sensitive material to be tested is placed in contact with the exposing scale, emulsion side down. It is held in position by the exposure platen at the top of the equipment. When the exposure platen, holding the film or paper in contact with the scale, is depressed, a contact switch makes the flashtube pulse.

Mechanically, such an instrument is much more simple and easy to use than the incandescent type. It doesn't require a mechanical shutter because the flash time is determined by the electrical flashlamp circuit conditions. Three pushbuttons give automatically controlled selection of exposure durations of 1/100th, 1/1000th and 1/10,000th second.

The longest exposure time, 0.01-sec., which is the one most commonly found in every day photography, is useful for normal picture-taking control. A 0.001-sec. pulse is provided for those who use short peaking photoflash or low-voltage electronic flash equipment. Users of photographic sound-recording equipment, high voltage electronic flash units, or other high speed photographic recording instruments are provided with a 0.0001-sec. exposure duration. Thus the laboratory technician is enabled to study film and development characteristics falling in the range of high-speed photography. He can, furthermore, compare his results with those obtained in the normal 0.01-sec. range and thereby measure any reciprocity failure that may be present.

Light incident upon the exposure plane can be measured directly by use of a General Radio light meter Type 1501, which enables the operator to calibrate the total light from the sensitometer. After first removing the exposing scale, the exposure meter is positioned on top of the instrument with its collecting window coincident with the sensitometer exposure window. Meter and sensitometer are electronically interlocked by means of the extension cable.

Depression of the control button on the meter causes the sensitometer to flash and the meter to integrate and hold the light reading. Units of light thus measured in the exposure plane are in lumen seconds per square foot. Because D-log E characteristic curves and the like are generally presented with exposure units in meter-candle-seconds, it is necessary to multiply the resulting reading by a constant factor

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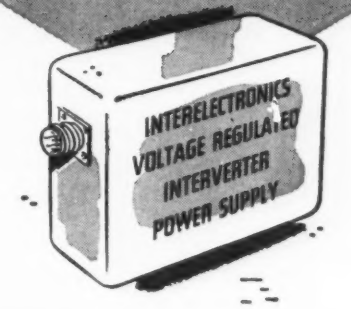

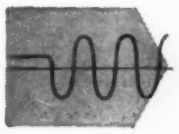

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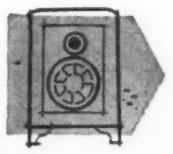

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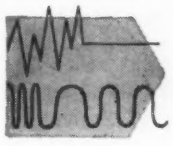

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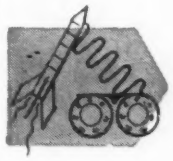

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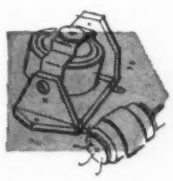

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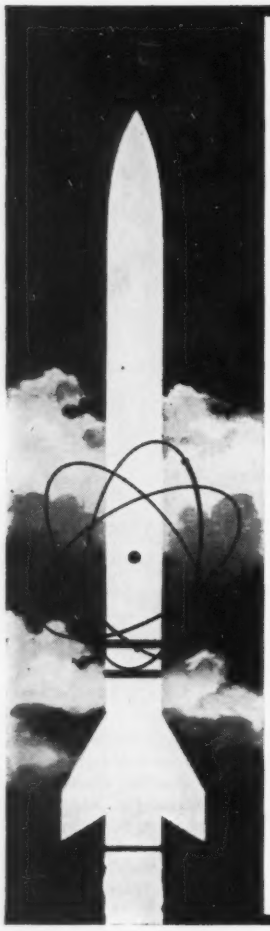

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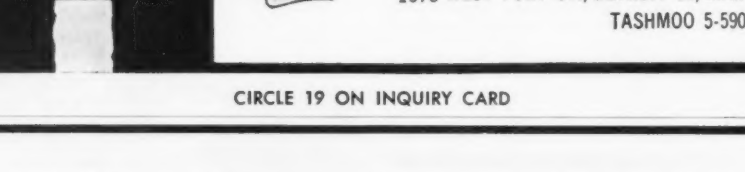

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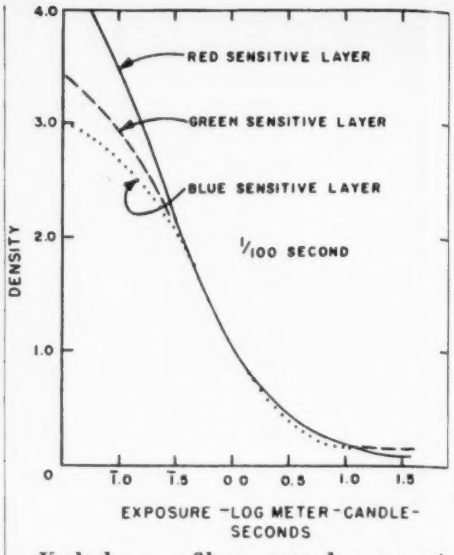
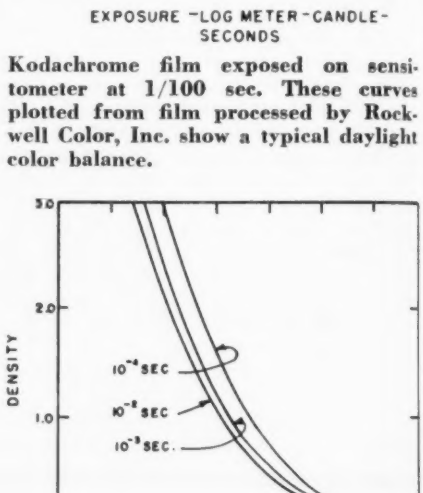
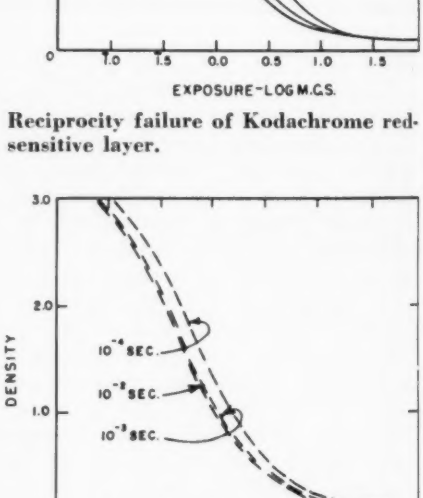


Kodachrome film exposed on sensitometer at 1/100 sec. These curves plotted from film processed by Rockwell Color, Inc. show a typical daylight color balance.

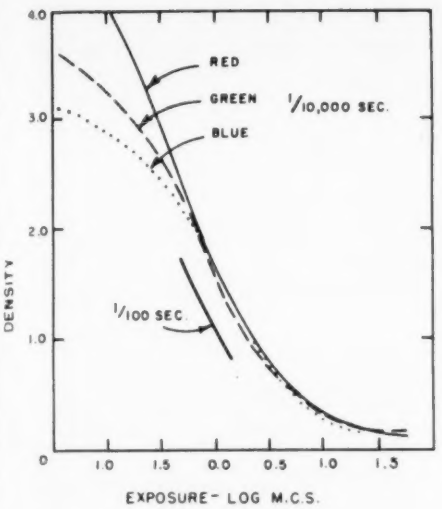


Reciprocity failure of Kodachrome red-sensitive layer.



Reciprocity failure of Kodachrome green-sensitivity layer.

When Kodachrome film is exposed for time shorter than 0.01 sec, it is interesting to note the effects of exposure-reciprocity failure on the three different layers. The blue-sensitive layer is apparently not affected for exposure times as short as 0.0001 sec. The green-sensitive layer begins to fail at 0.001 sec, whereas the red-sensitive layer starts to fail almost immediately at times shorter than 0.01 sec.



To bring Kodachrome film into neutral color balance at exposure time shorter than 0.01 sec, it is necessary to use color-correcting filters either over the film or over the camera lens. Thus for an exposure time of 0.0001 sec, it is necessary to use a 30Y and 20M filter to bring the three layers into balance. The above curves illustrate effects of such filters. Note restorations of color balance, but with loss of speed.

of 10.76 to obtain meter-candle-seconds. Thus a means is available for determining the exposure index in accordance with the 0.3 average gradient method as recommended by the American Standards Association.

Light output of the three available exposure durations is approximately 100mcs (meter-candle-seconds) for the 10^{-2}-sec. pulse, 5,000 mcs for the 10^{-3}-sec. and 40 mcs for the 10^{-4}-sec. exposure. These values are normalized to one value by the use of specially constructed variable-area filters inserted between the light source and the exposing step tablet. With the compensators in place, the amount of light incident on the exposure plane is on the order of 4 lumen-second per square foot for 40 mcs. This is enough energy for such emulsions as Kodalith or Reprolith or the new gravure-type emulsions for copying. More sensitive emulsions require additional filtration.

Design of the variable-area filters is presented as a line pattern to insure an even field of illumination in the exposure plane. The compensators have lines running lengthwise with respect to the exposing scale. For additional attenuation other variable-area filters are provided with lines running at right angles to those of the compensators. This arrangement prevents formation of a moire pattern of interference, and allows uniformity of illumination to be maintained in the exposure plane. Effective neutral-density values obtainable by this method range from zero up to a density of 3.0. It becomes a comparatively simple task to calculate the amount of attenuation by measuring the geometric areas through which light will pass.

Since this is a variable-area type of filter rather than a so-called neutral density type, light will pass through unaltered spectrally. The filter is, therefore, a true neutral attenuator. With proper spectral-quality light source, these filters may be used with color films such as Kodachrome, Anscochrome, Ektachrome, etc.

Relative spectral quality of an electronic flashtube filled with xenon can be made to approximate very closely the natural illumination of noon sunlight. Relative spectral output of the tube changes only slightly as a function of circuit conditions. Distribution of spectral energy is aproximately the same for 0.0001-sec. as for 0.01-sec.

Tube life, or the number of flashes a tube has cycled through, will not alter the spectral distribution of the light, although the total light will decrease somewhat. Repetition from flash to flash is of a high order, provided there is sufficient waiting time between flashes to permit full recharging of the condenser.

Another use for the sensitometer is that of studying resolutions of the various emulsions of interest. For this purpose the sensitometer is used simply as a contact-printing box. The exposing step tablet is replaced by a photographic-film, high-resolution target. It is further necessary to reduce the size of the light source. This is accomplished by replacing the compensator and variable-area filters with an opaque plate containing a ¼-inch hole in the center through which the light will pass. This will create some fall-off in light toward the ends of the exposure window, but exposures made in the central region will be satisfactory. Neutral-density filters may be placed over this hole if further attenuation is necessary. The film to be tested is placed emulsion-side down, in contact with the resolution target.

Additional applications of the instrument include process control, film-speed testing, analysis of latent image-fading characteristics, color film balance, and study of effects on film characteristics subjected to gamma radiation fogging.

Circle No. 227 on Inquiry Card

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

types: ALL INSULATIONS
including polyvinyl chloride; asbestos; silicone rubber; Teflon; Kel-F; polyethylene; Nylon; etc.

conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

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WALLINGFORD, CONN. / YORK, PENNA.
CIRCLE 21 ON INQUIRY CARD

14-CHANNEL TAPE RECORDER

Differential Capstan Drive Produces Constant Tape Tension Against Heads

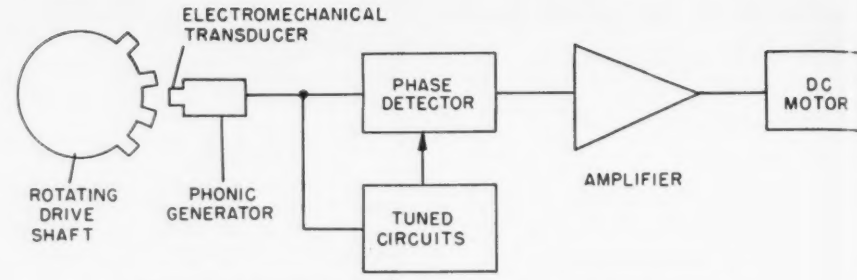
To effectively isolate the variations in tape tension that arise from rotation of supply and take-up reels, the new Mincom instrumentation tape recorder uses a differential capstan drive. This system, called the "Isoloop" system by the manufacturer, Mincom Division of Minnesota Mining & Mfg. Co., holds the magnetic tape on constant tension against the heads and eliminates variations that might normally cause serious wow and flutter. The result is improved recording and playback performance.

In addition, dynamic braking in the recorder stops the tape gently without employing mechanical friction of any sort. The manufacturer claims that optimum tension is on the tape at all times, and better storage conditions prevail than were before possible in magnetic tape recorders.

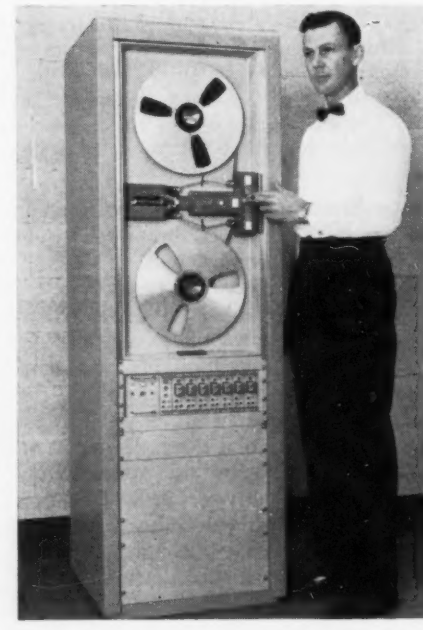
A standard 14-inch diameter tape reel with NARTB hubs provides 24 minutes of running time at sixty inches per second. The same 7200 feet of 1.0 mil tape is rewound in two minutes. The recorder can be furnished to accommodate larger reels.

Use of unitized solid-stage plug-in modules has produced a recording system that can be changed from direct recording to frequency-modulated or PWM telemetering use in a few seconds. The tape drive mechanism is also a plug-in type device: changeover from ½" 7-channel tape to 1-inch 14-channel tape can be made quickly.

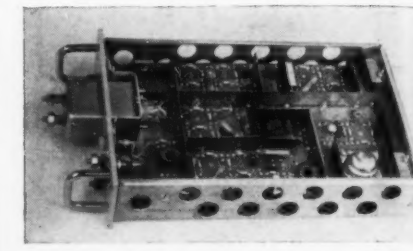
Tape speeds are controlled by a unique electronic speed control system. Instantaneous speed changes are made possible by the use of d-c motors. Control is accomplished by monitoring the tape speed continuously with a phonic generator on the drive motor shaft. This speed transducer is connected to a phase detector through reference tuned circuits that are selected by push buttons. The output of the phase detector in turn feeds a power amplifier. The current output of the amplifier controls the speed of the d-c motor to such an exacting degree that total wow plus flutter does not exceed 0.1 percent. This peak flutter specification includes all mixed components from 0.5 cycle to 4000 cycles per second, as measured at 60 ips tape speed.



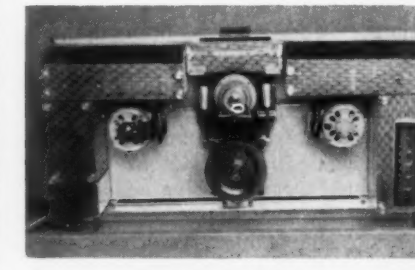
Electronic speed control system of Mincom tape recorder.



Electronic speed control is accomplished on the new Mincom C-100 instrumentation tape recorder by push buttons. The speed control buttons may be remotely located, e.g., at a control console.



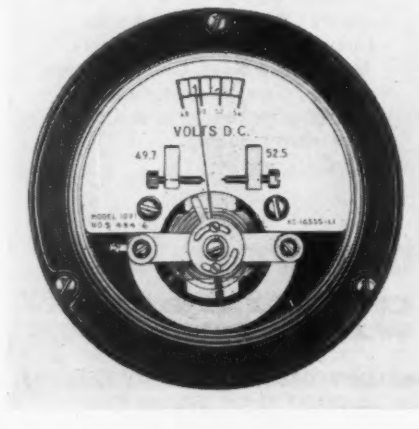
Rugged Mincom electronic modules contain solid-state components designed to produce virtually noise-free recordings.



The "Isoloop" differential capstan drive effectively minimizes wow and flutter. D.C. motors enable electronic speed control, with no troublesome belts to change.

Circle No. 228 on Inquiry Card

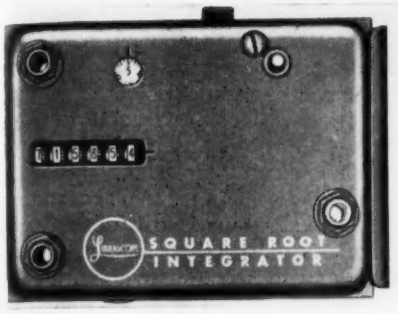
Hi-Torque Sensitive Relay



A high torque instrument-type relay with non-locking non-magnetic contacts uses a large core magnet, self-shielding moving coil mechanism, and offers increased sensitivity and better contact reliability because of its high torque characteristics. Relay has a d-c sensitivity of 25 microamperes, and an a-c sensitivity of 50 microamperes for contact closure. The 3.5-inch diameter unit has a scale length of 14 degrees, and maximum zero suppression is 14 scale lengths with a minimum of 10 microamperes on scale.

Designed for flush mounting on panels, the relay is rear connected and the front is removable for contact adjustment or zero correction without dismounting. Contact capacity is either 50 or 200 milliamperes at 6 volts d-c, depending upon the relay sensitivity, and contacts may be set as close as three degrees on zero-left instruments or 3-0-3 degrees on zero center. It is manufactured in ranges up to one ampere d-c, with a high limit of 5 milliamperes on a-c current and 50 millivolts to 100 volts a-c. Weston Instruments, Division of Daystrom Inc., Newark 12, N.J.

Circle No. 86 on Inquiry Card



Square-Root Integrator

Compact square-root integrator provides a means of continuous totalizing flow automatically. Specifically designed for use in standard flowmeters that utilize the output of conventional sensing elements, Librascope's Square-Root Integrator has a wide range of applications, including that of pressure corrector on positive displacement meters. The new unit can also be adapted to miniature strip chart flow recorders, forming an electro-mechanical integrator.

Utilizing a double disc and ball integrating mechanism, a recent Librascope development, the integrator fulfills the need for an accurate method of measuring flow. With a given speed on the lower disc, the upper disc and counter turn at a speed proportional to the square root of the displacement of the balls from the center of the disc. Linearity of the square-root integrator is 0.25 percent of full scale, achieved with a repeatability of 0.05 percent of full scale.

Maximum recommended input speed of 60 rpm, combined with a full scale ratio between the time shaft and the counter of 2:1, provides the counter with a maximum rate of 300 counts per minute. The integrator has an input shaft torque of 0.35 inch-ounces maximum and a shaft rotation of 18 degrees 30 minutes. Maximum time shaft torque is 0.5 inch-ounces. Operating temperature range of the instrument is −40 to +150 degrees F. A pulse switch driven by the counter shaft results in the pulse outputs of 2 closures per revolution. The pulse switch provides information to remote counters, telemetering or data handling systems. Librascope, Inc., Commercial Division, Burbank, California.

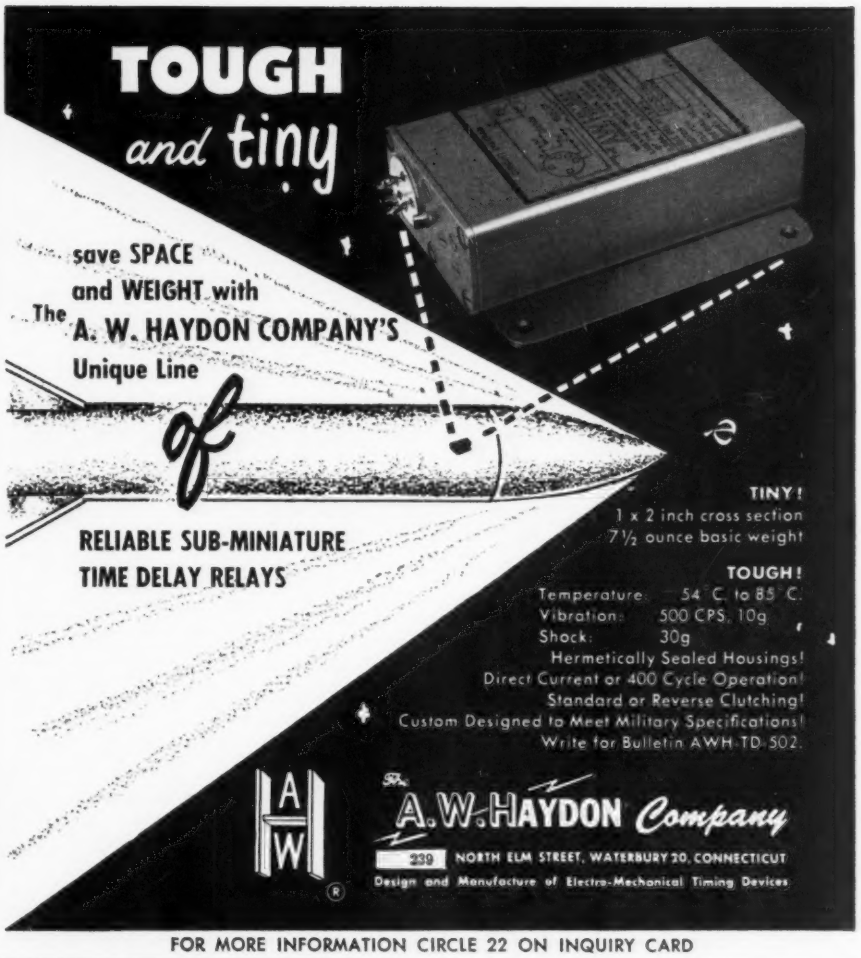
Circle No. 126 on Inquiry Card

WORTH FILING

Torque Vs. RPM Chart

Easy-to-read chart tabulates ounce-inch torque vs. RPM at stated horsepower, and gives engineering data in ranges from 1/2000 H. P. to 1/3 H. P. and from 1 to 14,000 RPM.

Source: John Oster Manufacturing Co.
Avionic Division Racine, Wisconsin
For your copy: Circle No. 109 on Inquiry Card.



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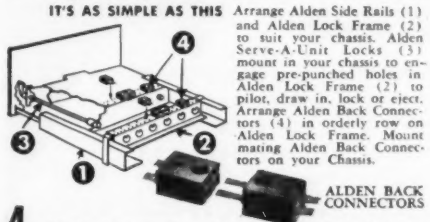

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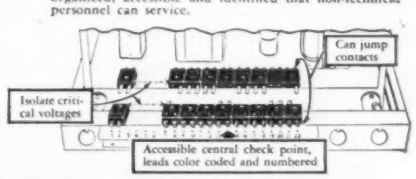

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FOR MORE INFORMATION CIRCLE 23 ON INQUIRY CARD

NEW TECHNIQUES

PORCELAIN-TO-ALUMINUM SEAL

Fusing Produces Chemical Bond

Cross-section view of top of bushing shows chemical bond between porcelain and aluminum.

A mechanically reliable, vacuum-tight seal results from bringing high-purity molten aluminum into contact with porcelain or other alumina-silica ceramics under carefully controlled temperature and temperature-change conditions. The technique requires no intermediate materials and no costly vacuum or atmosphere heat treatments.

Still a laboratory development by Westinghouse Electric ceramic materials engineers, the new seals can be used in transformers, circuit breakers and capacitors where the substitution of aluminum for steel or other structural materials is desirable.

The new technique eliminates disadvantages of other methods for making the seal: failure by leakage of mechanical seals (threads or shrink fits) caused by differences in thermal expansion, and leakage of organic sealing and gasketing materials that deteriorate under ambient conditions of apparatus use. In addition, other methods of making a chemically bonded seal between porcelain and aluminum require numerous costly intermediate steps.

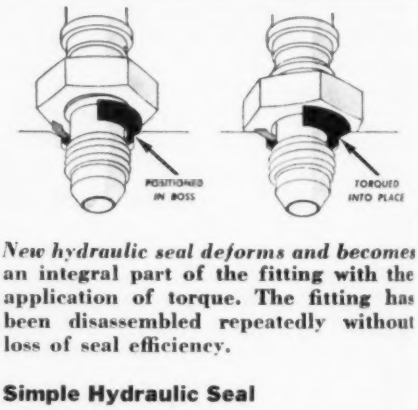
Temperatures and holding time at temperature are critical and depend on composition of the porcelain. Rates of heating and cooling are also important in preventing damage to the porcelain by thermal shock and achieving desirable grain structure in the aluminum.

Photomicrographs show a chemical bond between the two constituents. Thickness of this bond is dependent on composition of the porcelain, temperature and the time at temperature.

Mechanical tests have shown the bond material is stronger than either the aluminum or the porcelain. In fact, when a seal is destructively tested either in tension or shear, failure occurs seldom at the joint.

The large difference in thermal expansion between aluminum and porcelain is accommodated by the aluminum. Since the aluminum is of high purity, it is very soft and can flow to relieve stresses due to thermal expansion mismatch. Seals must be designed so as to have the porcelain in compression and the aluminum in tension. To date, successful seals have been cylindrical, with the porcelain surrounded by and compressed by the aluminum.

Circle No. 83 on Inquiry Card



***New hydraulic seal deforms and becomes* an integral part of the fitting with the application of torque. The fitting has been disassembled repeatedly without loss of seal efficiency.**

Simple Hydraulic Seal

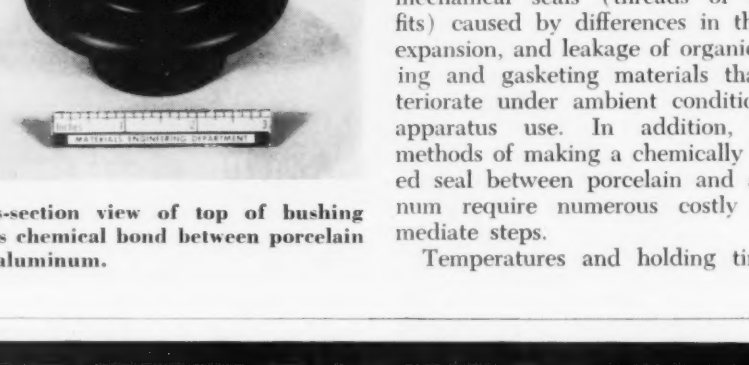
Testing of hydraulic components of navigation and other automatic systems consumes a large part of the cost and time of prototype programs. Frequently after days of work setting up a test in an environment chamber, failure occurs because of a seal failure with the result that the whole test has to be repeated even though the leak can be fixed in a few minutes.

After searching the market for a satisfactory seal, Autonetics' engineers began work on their own ideas under a company sponsored research program. "The result," they say, "is so simple that each engineer who sees the new seal wonders why he didn't think of it."

The new seal, which looks like an ordinary washer, is made of aluminum, stainless steel or Iconel-X. Tests indicate that the seal is effective from −360°F to 1200°F depending on material used from 0 to 10,000-plus psi. Automatics, Downey, Calif.

Circle No. 80 on Inquiry Card

Brew Delay Lines



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CIRCLE NO. 47 ON INQUIRY CARD

Optical Gage Reveals Condition of Deep Bores

An optical spindle, mounted on a precision ground base and used in conjunction with a standard illuminated microscope makes it possible to visually examine the inside walls of deep bores, cored holes and square or round tubing in diameters as low as 0.125. The part to be examined is placed on the correct size optical spindle and the microscope is focused on the reflector of the optical spindle, thus revealing, with magnification, true condition of the wall. Location of annular recesses, or lands, can also be measured with this instrument by using the line that runs horizontally across the face of the reflector and that is calibrated from the base. By using a collar, as shown in photo, the line is brought tangent to the land or recess, the collar is locked into position, part is removed and the dimension from collar to base is subtracted from the known calibration, which is stamped on the base. The difference is the location of the land or recess.

The gage is made of hardened and ground tool steel and can be used for production line inspection, as well as final inspection. Solrac, Inc., North Hollywood, Calif.

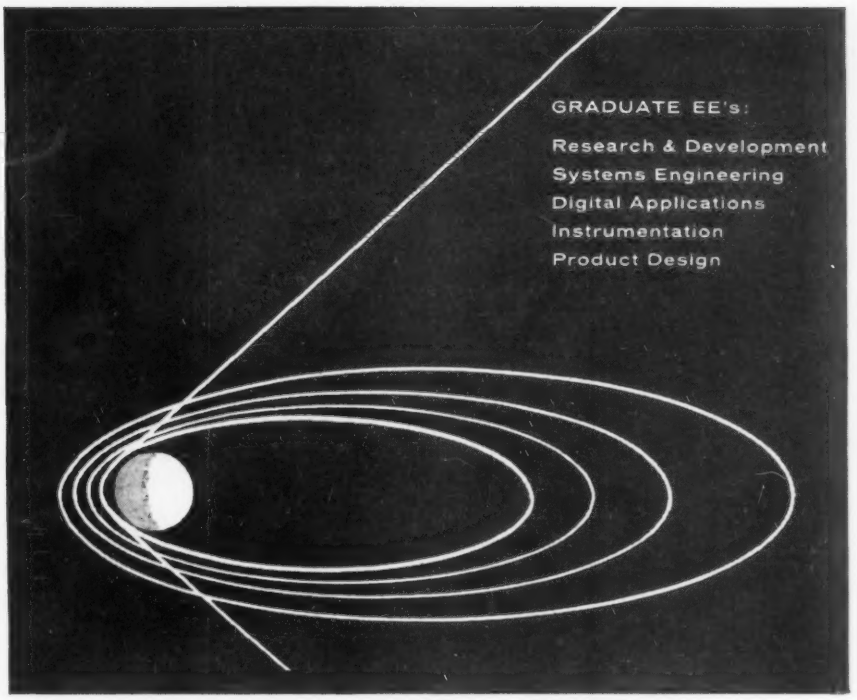
Circle No. 91 on Inquiry Card

Electrical Insulating Materials

12-page illustrated bulletin describes in text, tables and pictures the characteristics and application range of insulating materials which are chemically, physically and electrically compatible. Includes technical data on available products, such as mica mat, varnished cloths and papers, insulating varnishes, wire enamels, Irrathene irradiated polyethylene, sealing and filling compounds, insulating finishes and adhesives. For use in specifying compatible materials for electrical insulation systems.

Source: General Electric Company
Schenectady 5, New York.

For your copy: Circle No. 117 on Inquiry Card



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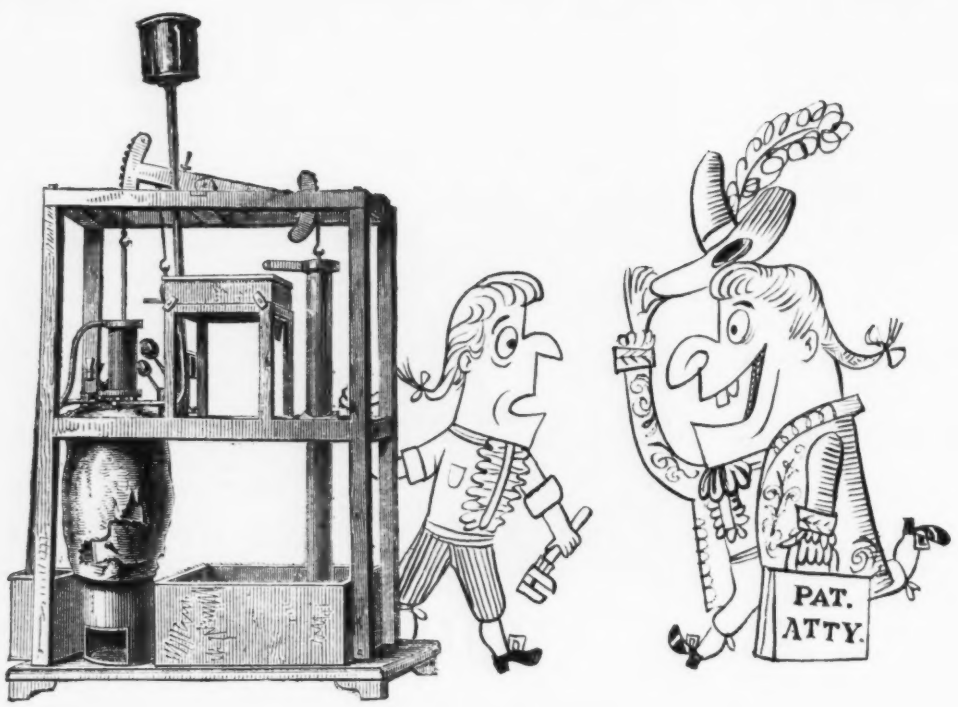
CIRCLE 24 ON INQUIRY CARD

MANAGEMENT



IF IT'S OBVIOUS, IT'S INVENTION?

David A. Rich, Staff Columnist

"How can this be invention, it's obvious!" How frequently I've heard this cry of incredulousness from the mouths of otherwise mature engineers. To the layman, and I must include most engineers in this category, an invention means something new and generally fairly ingenious. The answer to the question: "What is invention?" depends on each fact situation and can really only be answered after all factors involved have been thoroughly evaluated. Because there is so much confusion about this concept, it seems worthwhile to consider some of the background legal and practical factors involved.

BACKGROUND

A patent, in modern terms, has been characterized as a contract between the Government and the individual. In this contract, the Government gives the inventor the right to exclude others from making, using, or selling his invention. In return for this, the inventor is bound to make a complete disclosure to the public. He is bound in fact, in essence to dedicate his findings to the public. Going back to the Year One, this idea was generated by the thought that the Sovereign, the King, the Emperor, or whatever, would gain a great deal if he could somehow motivate the citizens to find better ways of doing things and introducing these new ways into his particular country. From that thought arose the notion that the fellow who takes the trouble to find or develop new machines should be rewarded. The reward took the form of a grant or patent from the king, which was in effect a monopoly over a new device or process.

At that time it took an extraordinarily long period of time to go from the birth of a new scientific idea to a practical device embodying the idea. It just never occurred to anyone to provide a stimulus to pure scientific investigation, primarily because of the remoteness of the cause to the effect. Classically, the motivation for the scientist has always been an intense curiosity as to the nature of things, a search for the ultimate truth. And furthermore, it was quite clearly a waste of time anyway; no country could afford to have too large a percentage of the population sitting and contemplating their navels. Such activity was regarded as seldom in the best interests of Mankind. Historically there is no precedent for rewarding physical scientists patents for their discoveries, as such.

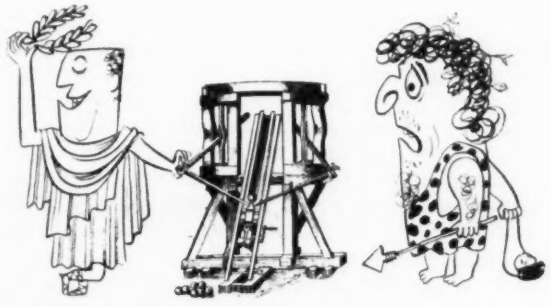
Of course, there has always been some understanding that speculations of physical scientists sometimes lead to beneficial advances. After all, look what Archimedes did when he launched rocks with a then unique launching method, using a catapult. He used the rocks to knock out enemy ships. (Note that invention of the catapult was, indeed, born by the generic mother of necessity—WAR.) But in applying scientific principles to the particular problems of building a catapult, Archimedes was not fulfilling his real mission in life. He merely recognized it was possible to build such a machine by virtue of his studies in the realm of mechanical leverage systems. He could get a patent on the machine, but not on his scientific ideas.

In more recent times, Edison was faced with a need for producing an electric light bulb with a useful life. Now, it turns out that at the time Edison became interested in such things the scientific basis was well established. Electric light bulbs were quite well known. The whole idea of putting an electrically connected incandescent filament in an evacuated glass envelope had been realized. Edison's "fundamental" invention consisted of adding a carbon filament of specified

dimension to what was already known. In this way, he advanced the life of electric light bulbs from a few hours to several hundred hours. This represented a tremendous step forward, firmly establishing the electric light bulb as a useful device. In terms of achievement, it represented a high degree of tenacity, persistence, etc. but surely not scientific genius. Nevertheless, Edison *did* produce an electric light bulb that really worked. The notion "here is the man who provided the device or the process that really works" is basic in modern patent law.

A corollary of this notion is the concept—axiomatic in patent law—that discovery of a scientific principle is not patentable per se. Thus, Newton's "Principia Mathematica" or Einstein's "General Theory of Relativity" were not fashioned of the stuff that makes for patents. In spite of a much critized Supreme Court decision involving a thing called "flash of genius", it is not a requirement of invention that it be ingenious. In fact, ingenious devices may not be patentable. In the same sense, an inventor need not be a genius.

In modern patent-law sense, the concept of invention is so pragmatic that it includes what is technically termed "actual reduction to practice", meaning actual construction and successful operation of a device or method. Invention is not cerebral in character. Of course, invention includes conception. The conception is not invention, however. The conception itself is a kind of mental gymnastic that, standing alone, is incomplete. Until such time as a device has been built, constructed, tested, and operated successfully, no invention exists. An element of invention is novelty. The device or process must be new. It must be different from anything that is already known. It is new, different, and useful.



PATENTABILITY

Having broadly discussed relationships between scientific ideas, inventions and patents, let's consider more explicitly the legal principles directed to patentable inventions. One of the most difficult concepts in law to define is patentability. Under the most recent expositions of the law in the United States, an invention is said to be patentable when it is indeed new, when it is useful, and—a delightful concept—when it is not obvious to one of *ordinary skill* in the art. In other words, something reflecting insight beyond what can reasonably be expected of the ordinary skilled mechanic must have happened.

I mentioned earlier that an invention to be complete includes actual reduction to practice. This is true but there is now a concept in the law called "constructive reduction to practice." At one time the Patent Office required a working model with every application for a patent. This is no longer the case. Actual filing of a patent application and issuance of a patent is considered to be "constructive reduction to practice." By its very character, a patent discloses sufficient information to one skilled in the art to practice the invention. It is therefore tantamount to actually building and testing the device. This concept gives rise to the great flood of what is familiarly termed "paper patents." I must say that paper patents are really patents and they are no less real because the device in fact has never been built.

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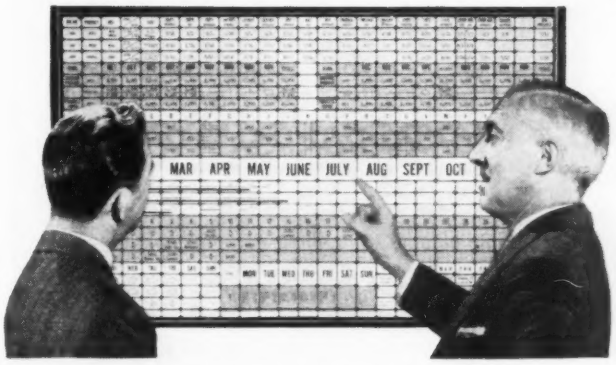

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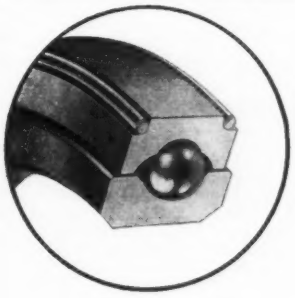

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Of course, it is very easy to be fouled up by failing to provide sufficient information to build a truly operable device. If the description is indeed inadequate for one skilled in the art to build the device or follow the method, the patent is invalid. Of course, not all of the details are necessary. A patent is designed to teach people with ordinary skill in the art; they, not necessarily the ordinary layman, must be able to follow the teaching of the patent. This distinction sometimes leads to disagreements—even lawsuits.

IF IT'S NEW, TELL YOUR PATENT ATTORNEY

No better mechanism exists than a bull session on a given device to acquaint engineers with what a patent attorney is looking for. At an engineering conference concerned with a new device about to be marketed, the entire device is generally scrutinized and analyzed with a fine tooth comb. One good way of extracting information as to what has been done that is new and different—and this is the beginning—is to point to an aspect of the design, and then ask the designer what he had in mind, what the problems were, what his discarded attempts were. In this way the group can gather a feeling for what is or isn't an obvious approach; i.e. the approach that would occur to a man who is given the problem first time.

In general every engineer feels that what he has done is obvious. The term obvious is a dirty word in patent law. If it's obvious, it's obviously not patentable. But let's not get caught in semantics here. Any development that an engineer has proposed is, of course, obvious to him. It was his insight after all that provided the solution to the problem. It is important to understand though that the question is not what is obvious to the man who did the job; the question is *what is obvious to the ordinary engineer faced with this problem*. The answer to such a question is much more complicated and subtle. It depends on the state of development in this particular field, the intensity of the effort in the field, how many people are working towards the same end, and how long has the work been going on. Although a contribution may appear slight when viewed with peculiar clarity provided by hindsight, if it is made after many years of unsuccessful efforts by many workers in the field, strong evidence of patentability is established.

It's not enough that the idea proposed or the design proposed is simple. Simplicity does not preclude patentability. More frequently than not, I might say, simplicity almost reaches the essence of patentability. It's my experience that the more complicated the device, the easier it is to patent and, frequently, the less contribution to the art it represents.

Philosophically it may be a good idea for engineers to worry about the character of invention. But it's not very practical. It takes quite an expert to define not only what is invention, but what's more important, what's patentable from a legal point of view. The engineer himself is not always aware of the character of his contribution. Even if it's "obvious" to him, it may in fact reflect profound insight of the type that clearly establishes patentability. (Note that most work done in modern electromechanical research and development lies in advanced areas dealing with unsolved problems. Consequently, the probability of a particular problem solution providing a patentable invention is very great.) This blindness of engineers to their own contributions suggests a good rule for them to follow—"If it's new, tell your patent attorney."

A very important factor in determining what is patentable is close liaison between the engineer and the patent attorney. There is never enough communication between the two. Perhaps the worst situation exists when the patent attorney is removed from and has no direct contact with the inventor and his environment. In such a situation the patent attorney has to depend upon the words the inventor uses in defining his invention and such insights as he derive from the de-

"How about a joint patent?"

scription of the device and its operation. This is a very inadequate basis for analyzing complex technical advances.

Expenses involved in preparation and development of a patent position are quite great and are properly considered an investment. Evaluating patent investments requires a peculiarly objective viewpoint. Ordinarily and at best the value of a patent at the time an application is filed is rather speculative. Patents should be evaluated on the basis of potential return or present need—in the same light as any other investment. This gets into the problem of whether or not patents are desirable for a given individual or concern—an area worthy of a good deal of discussion, and, yes, we shall talk about this. END

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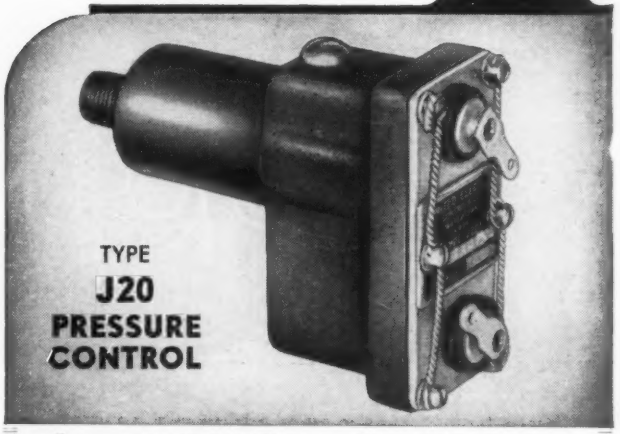

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DESIGN TIME SAVER

SPRINGS

by W. R. Johnson

Assistant Director of Research
Associated Spring Corporation
Bristol, Conn.

HOW TO DEAL WITH HIGH TEMPERATURES

Some Solutions to the Problems of Design and Selection of Materials

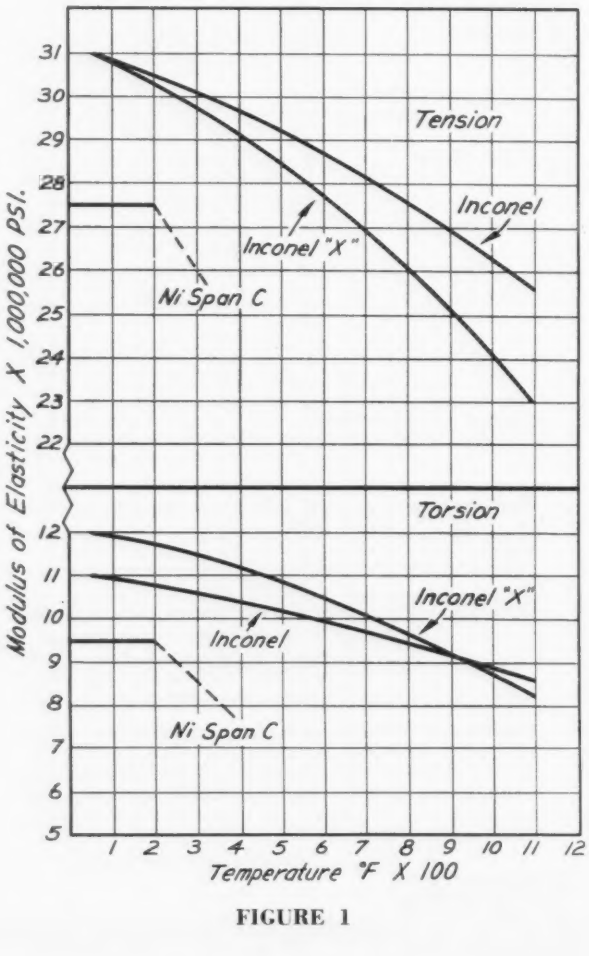

FIGURE 1

Elevated temperatures create two major problems for springs: setting or relaxation under load, and loss of rate (or stiffness) due to decrease in elastic or torsional modulus. By proper choice of materials and by certain design changes and processing modifications, you can now provide for high temperature operating conditions and obtain satisfactory performance under conditions once thought impossible.

Design of springs for successful operation at elevated temperatures is one of the most difficult problems facing the product-engineer today. Demand for more power from automotive engines and for higher speed aircraft means inevitably that springs in these engines will be operating at higher and higher temperatures. Already springs in automatic transmissions are operating at temperatures of 350° and up, and manufacturers of jet engines would like to operate at highest possible temperatures. Seals and components powered by springs must still continue to function at these temperatures.

An even greater problem is posed by springs that are vital components in instruments and control mechanisms to control guided missiles, meter jet engine fuel, and protect nuclear reactors. Ideally, the designer wants the spring not only to function from sub-zero temperatures up to elevated temperatures resulting from aerodynamic heating at high Mach numbers, but he also would like the spring to have the same push under all conditions. Even in domestic appliances such as in pop-up toasters and temperature controls of electric irons there are springs which the housewife expects to stand up for a long, long time.

From the user's standpoint, high temperature has one effect on springs: they do not carry the load expected. This effect results from two separate effects:

1. The spring loses in stiffness or "spring rate" because of decrease in elastic or torsional modulus of the spring material as temperature rises.

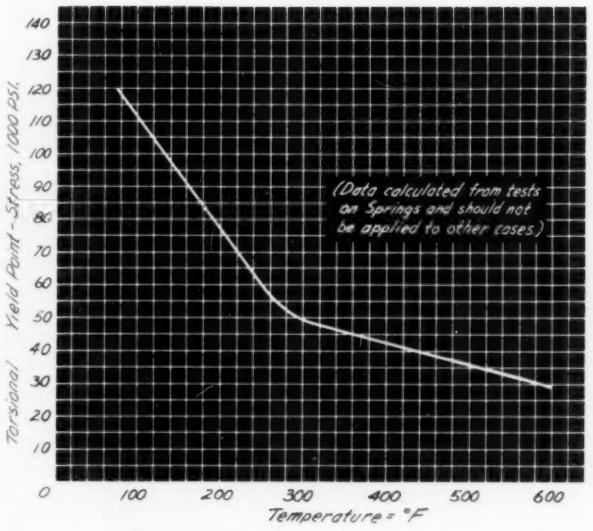

FIGURE 2

2. The spring sets or relaxes under applied load, which reduces the free length of the spring and hence its ability to absorb the load.

The effect of temperature on fatigue strength is not so important, because stresses great enough to cause fatigue failure after repeated cycling would normally produce failure-by excessive relaxation first.

If we look at these from a mechanical and metallurgical basis, the situation becomes somewhat more complicated. As mentioned, part of the loss of load-carrying ability at elevated temperatures is due to the decrease in modulus. This may be calculated from readily available data and allowed for in spring design. However, set or relaxation of a spring under load at an elevated temperature appears to be due to a combination of three effects:

Yield point of the material drops at elevated temperatures, causing the spring to take permanent set at lower stress as a result of plastic flow of the material.

Residual stresses generally present in the spring are gradually relieved at elevated temperatures, and this relief is reflected as set of the spring.

A type of flow called anelastic flow takes place at stresses below the yield point. This flow is partly recoverable under certain conditions.

Of course, if operating temperature is sufficiently high, a metallurgical change may take place with consequent excessive relaxation. For example, a spring made of carbon steel cannot be used at temperatures approaching tempering temperatures, nor can precipitation-hardened alloys be used near age-hardening temperature. In this discussion we assume that the operating temperatures involved are below those at which any metallurgical changes take place.

HOW TO DEAL WITH REDUCED ELASTIC AND TORSIONAL MODULI

It is relatively easy to calculate a spring design based on the moduli characteristics at elevated temperatures, but the problem is much more difficult if the spring must maintain a constant rate over a wide temperature span. Then a material must be selected whose temperature coefficient modulus is close to zero or, more precisely, just sufficient to offset changes in spring dimensions due to thermal expansion.

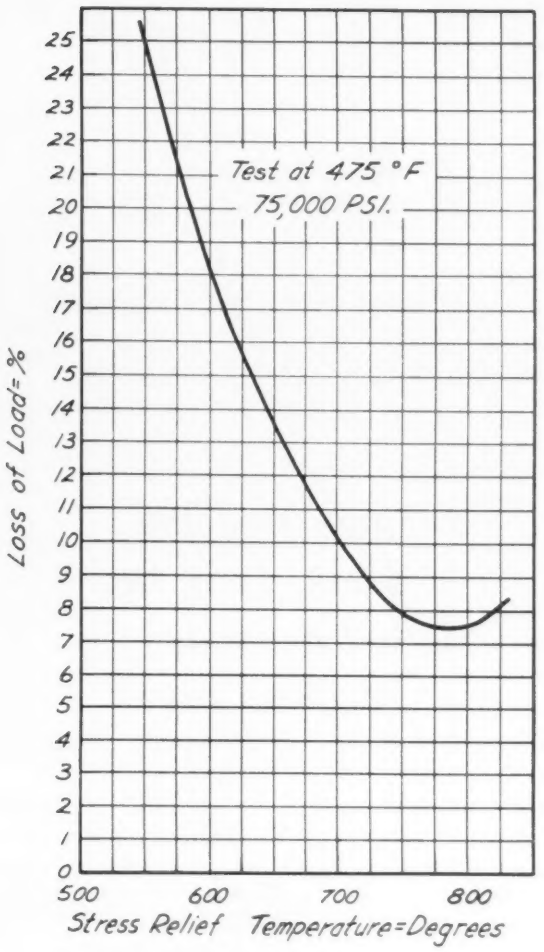

FIGURE 3

The choice of such materials is limited to those in the "Elinvar" family. Probably the best known of these is Ni-Span "C" — an age-hardening iron-nickel-chromium-titanium alloy. This material possesses a constant modulus of elasticity all the way up to temperatures of about 180 to 200°F. Above 200°, the modulus of elasticity changes rapidly and non-uniformly as the temperature changes (Fig. 1).

There is no way known at present to maintain a constant spring rate over a span of temperatures higher than this except by use of external compensating devices. In critical applications, such as jet-engine fuel controls, it may be easier to compensate over a wide temperature range a spring made of an alloy which has a constant and uniform temperature coefficient of elastic modulus than one made of an alloy like Ni-Span "C" with its changing temperature coefficient.

HOW TO DEAL WITH A DECREASED YIELD POINT

If a spring is to perform at maximum efficiency, it must be designed to carry as high a stress as possible. But metals have a lower yield point at elevated temperatures than at room temperatures, and as ambient temperature rises, yield point of the material may be lowered to the point where the spring will set under stresses that would normally be safe at room temperature (Fig. 2).

The only solution to this problem is to select a material whose yield point is sufficiently high to bear up under

continued on page 41

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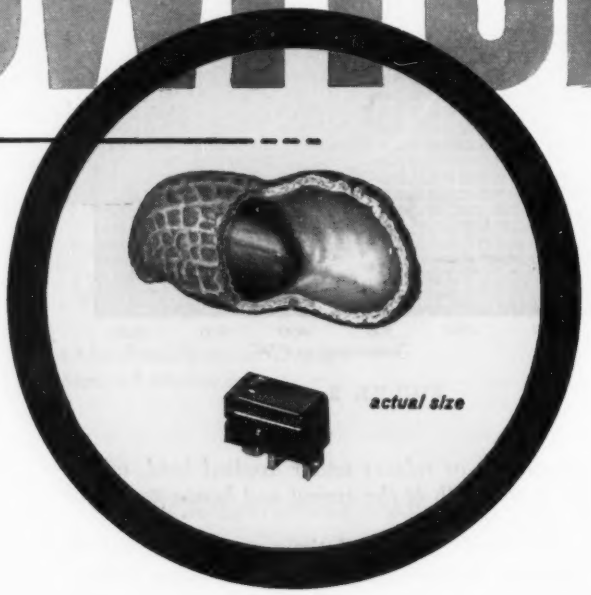

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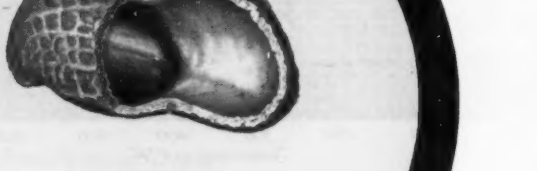

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Operating Force	approx. 200 grams (7.05 oz.) max.
Pretravel	approx. .010"
Contact Pressure	59 grams (1.76 oz.)
Overtravel	.005" min.
Movement Differential	.003" max.
Release Force	30 grams (1.06 oz.)
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CIRCLE 32 ON INQUIRY CARD

continued from page 39

desired operating temperature. Each material has a practical upper limit of usefulness. Above this temperature, yield point is so low that excessive set takes place, even if the spring is exposed to high temperature for only a short time. This set is true plastic flow and is not recoverable.

HOW TO DEAL WITH RELIEF OF RESIDUAL STRESS

Much of the load carrying capacity of springs used at room temperature comes from beneficial residual stresses. These may be the result of cold-working of the spring material in the coiling operation, or from the cold-drawing operation. Or, they may be the result of a set out or preloading operation performed on the spring, stressing the spring past its yield point so that beneficial residual stresses are induced. However, as the temperature rises these residual stresses are spontaneously relieved, and this relief causes relaxation of the spring or permanent set.

To protect a spring against such relaxation under high temperature, the designer must use manufacturing procedures that minimize and control these residual stresses. The spring should have maximum possible stress relief after coiling in order to minimize relaxation. However, stress relief may not be at such a temperature that the yield point or load-carrying ability of the spring is impaired. Figure 3 illustrates this effect for music wire springs. Stress relief temperatures of 400 to 500°, which give the best properties at room temperature, are far inferior to stress relief temperatures of about 750°F. At temperatures above 750° the material is permanently softened (Fig. 3).

Ideally, for minimum relaxation a spring should be heat treated completely after coiling, but such a treatment for many materials does not give a sufficiently high yield point, and it poses great problems in excessive spring distortion during heat treatment.

HOW TO DEAL WITH ANELASTIC FLOW

As defined by J. D. Lubahn, in "The Role of Anelasticity in Creep, Tension, and Relaxation Behavior", ASM Transactions, Vol. 45 (1953), pp. 787-838, anelastic flow is flow caused by a sufficiently low constant stress, which is non-instantaneous and is completely recoverable isothermally in a sufficiently long time. In other words, anelastic flow may occur, rapidly at first but continuing over a long period of time, even when a spring is loaded below the yield point so that no plastic flow takes place. If the load is removed and the same temperature maintained, recovery will occur at an amount and over a period of time similar to that which caused the deformation, until the original length is regained. Anelastic flow is analagous to hysteresis at room temperature. Figure 4 charts this behavior of Inconel wire springs.

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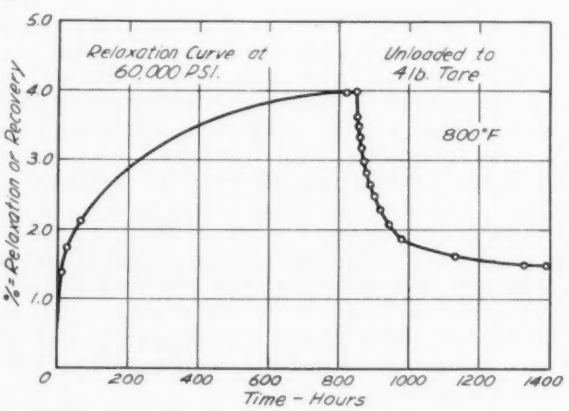
FIG. 4



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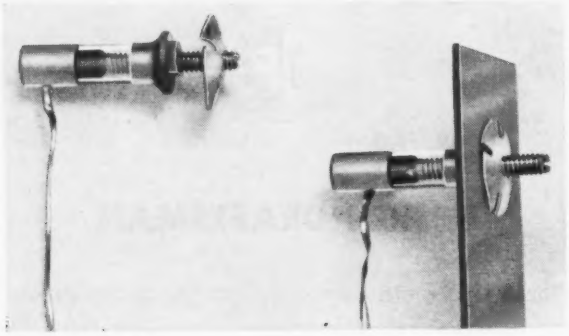

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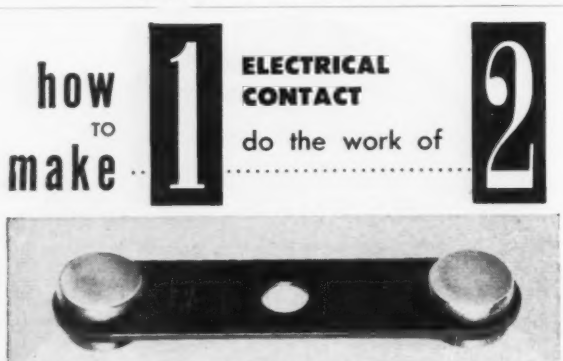

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continued from page 41

Probably most of the setting that takes place in properly designed springs operated at elevated temperatures is due to anelastic flow, for such springs have been designed to minimize true plastic flow. Relaxation measurements generally made on springs do not reflect this fact, for they usually measure total relaxation at room temperature, before the spring has had a chance to recover relaxation due to anelastic flow.

The net effect, however, is the same—the spring loses its load-carrying capacity—whether relaxation is due to anelastic or to plastic flow, in springs under constant load. Springs that are loaded intermittently at elevated temperatures but are maintained at those temperatures unloaded, however, may be expected to lose and regain their load-carrying capacity in cycles which depend on (and correspond to) the loading and unloading cycles. Such springs may thus perform considerably better than expected, particularly if the unloading cycle is equal to or longer than the loading cycle. Performance of such a spring cannot be predicted on the basis of experimental springs loaded at elevated temperature and then unloaded and measured at room temperature.

Anelastic flow can be minimized by a spring-making operation called heat setting: the spring is heated under load to a temperature higher than the expected operating temperature, and thus a portion of relaxation that might be expected to occur in service is removed in advance. The spring is coiled longer than finish size to allow for this heat setting operation. The exact mechanical or metallurgical explanation for the results is not fully understood. Heat setting may cause some strain-hardening by plastic flow. It induces a residual stress system which is beneficial and is not removed in service, and it also absorbs a part of the anelastic flow which would otherwise occur after the spring went into service. The net effect of heat setting is to produce a spring that can carry a greater load in service at elevated temperature than one designed without allowance for heat setting. However, such heat setting involves anelastic flow and residual stress patterns in addition to plastic flow, and a portion of the loss of height from the operation is recoverable. A heat set spring, if unloaded at operating temperatures, will gain in load-carrying capacity with time. In some springs this gain may be as undesirable as lcad loss. It is a difficult thing to design a heat setting operation that will just compensate for a potential load loss in service, and so far this is done primarily on an empirical basis.

SELECTION OF SPRING MATERIALS FOR HIGH TEMPERATURE SERVICE

Choice of material for a spring to be operated at elevated temperatures is first dictated by the level of those operating temperatures. As the temperature rises, the number of suitable materials decreases, and in general their cost increases. In particular, for very high temperatures, high-nickel or high-cobalt superalloys must be used, despite their high cost and difficulties involved in obtaining them. In the upper range of operating temperatures, selection of material is dictated by its resistance to metallurgical softening and/or to excessive relief of beneficial residual stresses.

Sometimes special processing can be employed. For example, music wire springs that must be used at 250°F can be stress-relieved after coiling at 750°F. instead of the more usual 450°F, with some sacrifice of performance properties at room temperature to gain improved performance at 250 to 300°F.

The following table gives a general guide to selection of the most common spring materials for operation at particular temperature ranges:

Constant Modulus to 200°F	Ni-Span "C", Iso-Elastic
Room Temperature to 300°F	Music Wire, Chrome Vanadium
300° to 450°F	Chrome Vanadium, Chrome Silicon, Stainless Steel
450° to 600°F	Inconel, High Speed Steel, Stainless Steel
600° to 900°F	Inconel X spring temper, High Speed Steel, Haynes 25
900°F and above	Inconel X #1 temper, S816

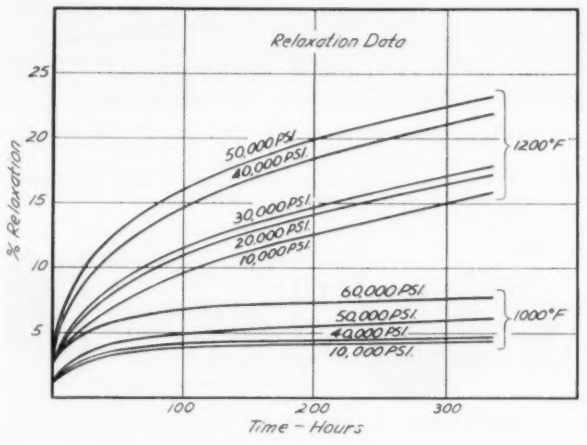
Engineering data commonly given for high temperature alloys can be quite misleading. Materials that are commonly used in turbine buckets, for example, at temperatures of 1500° and above, may be quite disappointing when used in springs at 1200°. Practically, springs can not be designed to the low stresses applicable to many of the structural parts, and amounts of creep that can be tolerated in other high temperature parts would render a spring completely useless. Often heat treatments recommended for super-alloys are not applicable to spring materials, because of low resulting yield point. Maximum temperature for which springs can be designed is generally limited by the metallurgical considerations. For example, Inconel X cannot be aged much above 1350° without some re-solution taking place. There is very little stress-carrying capacity above 1200° so far as spring design is concerned. However, occasionally a spring proves to be serviceable at high temperatures because of a combination of special heat treatments, low design stresses, liberal relaxation requirements, and intermittent loading which gives the spring a chance to recover. Figure 5 charts some data on performance of Inconel X #1 temper at temperatures above 1000°F. The low design stresses that must be used are evident from these curves.

CHOICE OF DESIGN STRESSES

As operating temperatures rise, the problem of anelastic flow reflected as relaxation of the spring becomes more and more critical. The level of stress at which measurable flow occurs is very low. In fact, some unpublished data obtained by the International Nickel Company indicate that relaxation is almost independent of stress at low stress levels. Heat setting would minimize relaxation at these low stress levels, but then growth due to recovery would become a problem.

continued on page 45

Figure 5



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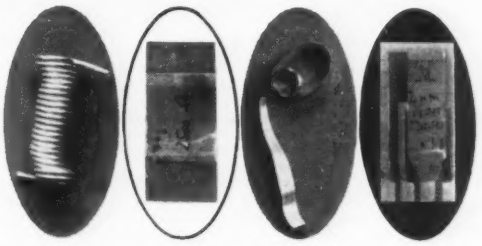

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At last you can take advantage of Bismuth's extreme sensitivity to changes of temperature and magnetic field intensity. Through an exclusive process, we have perfected Bismuth in ductile form . . . Bismuth that can be bent without crumbling and breaking. Available in insulated or bare wires, in special alloys for thermocouple legs, in wire form or grids for resistance controlled circuits and gauss meters, and in ribbons or plastic mounted films for Hall effects. No other material is so versatile in its application to control and testing instrument design.

HAS 1001 USES IN TESTING AND CONTROL INSTRUMENTS!

Write for Complete Information And Prices:

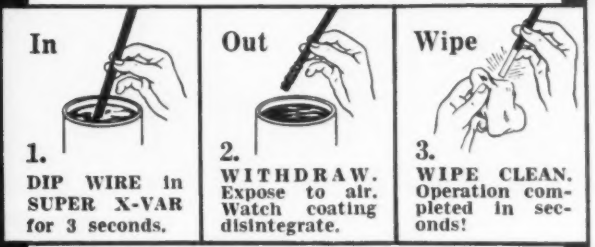
Fitzpatrick ELECTRIC SUPPLY CO.
446 IRWIN ST. • MUSKEGON, MICHIGAN

CIRCLE 37 ON INQUIRY CARD

NEW! REVOLUTIONARY!

SUPER X-VAR

Removes "Hard-to-Strip" FORMVAR, FORMEX, & ENAMEL insulation In Seconds!



1. DIP WIRE in SUPER X-VAR for 3 seconds.
2. WITHDRAW. Expose to air. Watch coating disintegrate.
3. WIPE CLEAN. Operation completed in seconds!

New Super X-Var quickly removes coatings that X-Var can't remove or removes slowly. Non-corrosive and leaves wire ready for soldering. Now in use by leading manufacturers of electrical products.

Request free sample for test use.

Fidelity Chemical Products Corp.
476 Frelinghuysen Ave., Newark 5, N. J.
International Division
15 Moore St., N.Y.C. • Cable "CHURCHIN" New York

CIRCLE 38 ON INQUIRY CARD

computing components instrumentation & controls

BY LIBRASCOPE

SHAFT POSITION TO DIGITAL ENCODERS AND READOUTS

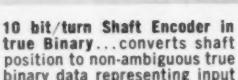
10 bit/turn Shaft Encoder in true Binary... converts shaft position to non-ambiguous true binary data representing input shaft position to 1 part in 1024 for each revolution. Used as input-output devices for true binary digital computers. **No external logic required.**

BCD Shaft Encoder... used where conversion to decimal form with ease is a requirement. All binary lines representing a decimal digit are parallel for ease of recording.

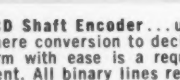
Sine-Cosine Shaft Encoder... presents sine and cosine functions simultaneously and independently. In addition, the limit one, quadrant and polarity data are supplied. Ideal for airborne automatic navigation systems, weapon control and tracking systems.

Digital Readout... performs logical brush selection operation in encoders using "V" scan. Also translates the unambiguous BCD encoder representation into parallel decimal form. Suitable for electric printers, lamp banks, etc.

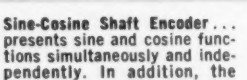
PLOTTING AND RECORDING EQUIPMENT



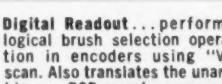
X-Y Plotter... for point or continuous plotting, with positive mechanical drive for recording graphic data. Several models available.



Punched Tape Converter... converts the digital information read from punched paper tape into input signals to the Librascope X-Y Plotter.



Punched Card Converter... converts data from IBM punched cards into analog input signals to the Librascope X-Y Plotter.



X-Y Decimal Keyboard... consists of a three-decimal bank for each axis with associated plus-minus keys.

DIGITAL AND ANALOG COMPUTER COMPONENTS

Magnetic Storage Drums... for medium storage applications; capacity 131, 072 non-volatile bits; several speeds; clock frequency 130 kc. Other models available.

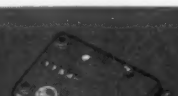
Read-Record Heads... for high frequency, non-contact recording applications in magnetic memory systems; high read-back signals. Transistor windings available.

Hollow and Solid Shaft Differentials... designed for high accuracy in additive and subtractive operations... has primary applications to angular velocity, sums and difference, and sequence operations.

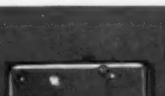
Ball-Disc Integrator... for use in totalizing, rate determination, differential analyzers, closed loop servo-element, variable speed drive, temperature correction, etc.

FLOW, VOLUME, AND AREA COMPUTING EQUIPMENT

Flow Computer... extracts square root and continuously integrates both differential and static pressures for applications such as orifice measurement of gas.



Linear Integrator... for systems or instruments requiring integration, average computations, direct or remote reading... mounts in strip chart recorders.



Square Root Integrator... designed for the flowmetering industry to provide an economical, continuous, and compact integrator for automatic totalization of liquid flow.

Planimeters... for miniature strip chart recorders for simple integration with variable speed control; 2 models: square root and linear.

COMPUTERS, CONTROLS AND COMPONENTS

Also Process Control Computers,
Automatic Data Logging and Control Systems
for Industry and Government

Write for additional Information

Librascope's use of the LGP-30 computer simplifies complex design and production problems, and assures computer-engineered quality in meeting delivery schedules.

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GPE GENERAL PRECISION EQUIPMENT CORPORATION

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CIRCLE 39 ON INQUIRY CARD

continued from page 43

At higher temperatures, work-hardened materials such as stainless steel, Inconel, and Inconel X relax excessively as a result of stress relief. The best materials, in this case, are those that can be age-hardened at a high temperature after the coiling of solution-annealed material. Still better relaxation behavior can be obtained from materials that have been annealed and aged *after* coiling, for then a minimum of residual stresses would be present. But such heat treatment would result in a low yield point and low stress-carrying capacity.

In short, the design of high temperature springs is complicated. We do not yet know enough to design such a spring *exactly*—it is necessary to confirm the design experimentally. This is especially true because the relationship of loading cycle to operating temperature affects performance of the spring so markedly. Some useful data are contained in a paper by R. G. Matters and R. E. Locken, "Materials for Helical Compression Springs for Use at Constant Deflection from 600 to 1400 deg. F.," ASTM Proceedings, Vol. 56 (1956), pp. 672-686, and in Bulletin T-35, "Inco Nickel Alloy Helical Springs," Published by the International Nickel Company. However, by applying what is known of metallurgical phenomena, and drawing on an experienced spring manufacturer's thorough knowledge of manufacturing techniques, springs can now be made to perform successfully in many applications once thought impossible.

Circle No. 232 on Inquiry Card

WORTH FILING

High Vacuum Techniques

Advanced European and American high vacuum impregnating, drying, degassing, and filling techniques of special interest to manufacturers and users of electrical distribution equipment, electronic components, and thermosetting organic compounds such as epoxy resins are described in a new 28-page brochure. Graphs and technical information detail the superior electrical and physical characteristics resulting from high vacuum processing. Photographs and schematic diagrams illustrate the cost-saving German techniques and equipment developed by Leybold-Hochvakuum-Anlagen, available through NRC. The bulletin presents quantitative information on the effect of high vacuum processing on dielectric strength and loss factor of insulation, advantages and mechanics of dielectric heating, vapor stream degassing, and tower drying and degassing of impregnants. A translation of a technical brochure prepared by Leybold is believed to be one of the first reports on the benefits and techniques of modern German practice to be published in English.

Source: NRC Equipment Corporation,
Newton, Mass.

For your copy: Circle No. 129 on Inquiry Card

WORTH FILING

Toroidal Cores

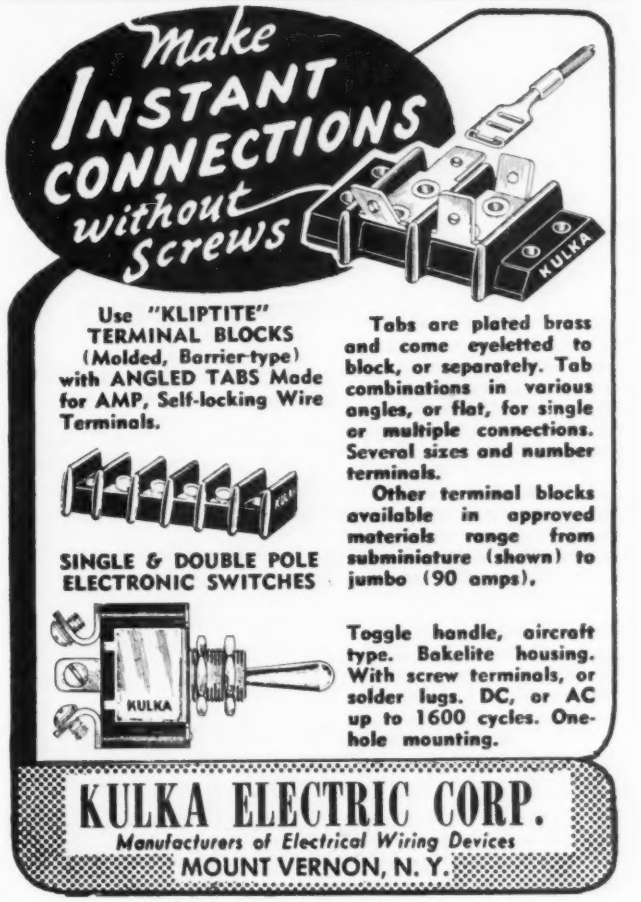
12-page handbook for designers on the use of Genalex toroidal cores covers such things as permeability, temperature coefficient of inductance, d-c stability, core size and finish. Complete graphs and technical data on the loss characteristics of Genalex cores are presented. The handbook charts physical and electrical properties of Genalex III cores and design notes on the use of toroidal cores are included.

Source: Wallace E. Connolly and Company
Menlo Park, California

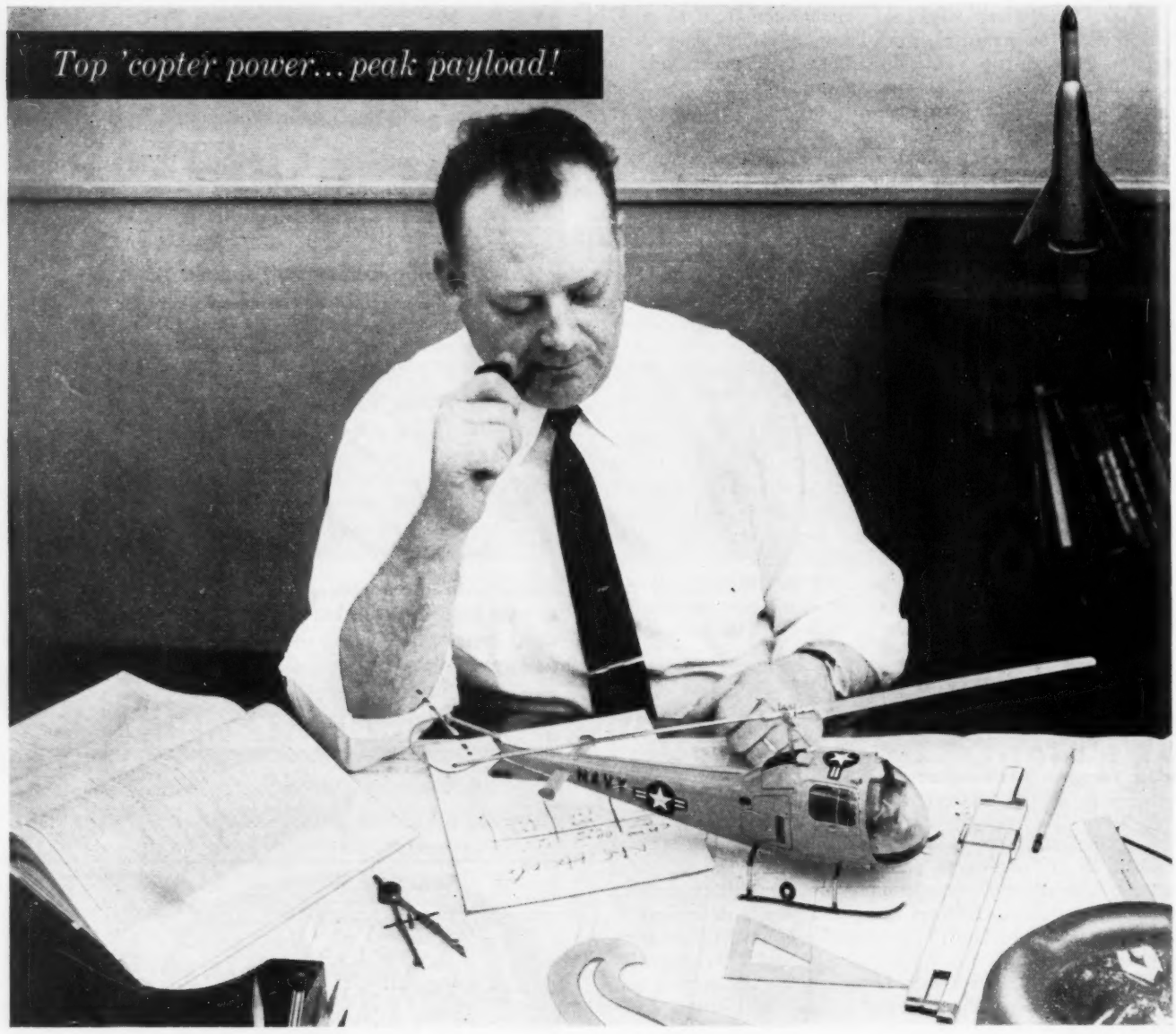
For your copy: Circle No. 168 on Inquiry Card

push-pull
CONTROLS
Compression & Tension Type
Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.
Three Types:
1. Light Duty—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. Heavy Duty—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
3. Extra Heavy Duty—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.
Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD 58.
SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

CIRCLE 40 ON INQUIRY CARD


Make
INSTANT
CONNECTIONS
without
Screws
KULKA
Use "KLIPTITE" TERMINAL BLOCKS (Molded, Barrier-type) with ANGLED TABS Made for AMP, Self-locking Wire Terminals.
Tabs are plated brass and come eyeletted to block, or separately. Tab combinations in various angles, or flat, for single or multiple connections. Several sizes and number terminals.
Other terminal blocks available in approved materials range from subminiature (shown) to jumbo (90 amps).
SINGLE & DOUBLE POLE ELECTRONIC SWITCHES
KULKA
Toggle handle, aircraft type. Bakelite housing. With screw terminals, or solder lugs. DC, or AC up to 1600 cycles. One-hole mounting.
KULKA ELECTRIC CORP.
Manufacturers of Electrical Wiring Devices
MOUNT VERNON, N. Y.

CIRCLE 41 ON INQUIRY CARD



YARDNEY SILVERCEL® BATTERIES ARE 66% LIGHTER, 35% SMALLER THAN ANY PREVIOUS HELICOPTER POWER SOURCE...

In a drive to increase the valuable "payload" capacity of its 47J Helicopter, the Bell Helicopter Corp. replaced the conventional lead-acid battery with a miniaturized YARDNEY SILVERCEL® Battery. Result: a reliable power source 2/3 lighter, 1/3 smaller and with 1/3 more power output. They also gained freedom of design and extra cranking endurance. With pace-setter Bell proving the point, it's small wonder that today, SILVERCEL® Batteries are being designed into every modern helicopter.

Up to 5 times smaller, 6 times lighter, and with a greater power surge than ordinary batteries of equal capacity, the SILVERCEL® Battery offers many new opportunities for imaginative applications. There are standard SILVERCEL® Batteries for such applications as remote-control work, communications equipment, portable power supplies, telemetering and instrumentation, as well as custom-built batteries for particular requirements. Write today for complete technical data.

WESCON BOOTH #1739

YARDNEY ELECTRIC CORP.

*"Pioneers in Compact Power"**

40-50 LEONARD STREET, NEW YORK 13, NEW YORK

Patents granted and pending.

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**Trade Mark*

MANUFACTURERS OF YARDNEY SILVERCEL®, YARDNEY SILCAD® AND YARDNEY ARCTIC* BATTERIES

CIRCLE NO. 42 ON INQUIRY CARD

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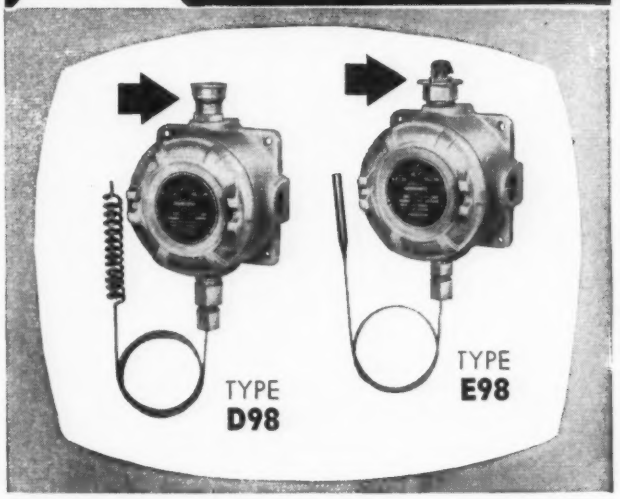
EXPLOSION PROOF
D98 | E98 TEMPERATURE CONTROLS



UNITED ELECTRIC has designed the D98 and E98 units to automatically and sensitively control the temperatures of gases, liquids and hot plate applications where explosive vapors and gases are present. Both units feature external, calibrated temperature adjustments. The E98 adjustments are made by a single-turn adjustment knob and pointer, while the D98 has a multiple-turn, micrometer type adjustment.

Temperature Ranges	Type D98 — 300° or 550° F between limits of −150° and +650° F. Type E98 — 100° or 200° F between limits of −150° and +650° F.
Thermal Assemblies	Various shapes and sizes of thermal assemblies available. Completely liquid-filled bellows, bulb and capillary assembly.
Switch Ratings	15 amps. at 115 or 230 volts AC, also 20 amps. or DC switches on specification.
Switch Types	N.O., N.C., or Double Throw, no neutral position.
Electrical Connections	Two, ¾" NPT conduit openings in enclosure. Internally-located terminal block.
Size & Weight	9¼" x 5¾" x 3⅞" — weighs approx. 8 lbs. 4 oz.
Enclosure	Class I, group D and Class II, groups E, F and G explosion-proof enclosures; cast iron base, aluminum cover.
ON-OFF Switch Differential	Fixed, uniform throughout specified range.
Mounting	Surface mounted in any position by mounting holes in each corner of base.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure, and vacuum controls. UE will gladly modify or custom-build a unit to meet your specifications. Consult a UE application engineer today.*

Write for Bulletin No. 3-1 for complete D98 data or Bulletin No. 3-5 for complete E98 data.

UE®
United Electric Controls
COMPANY
81 SCHOOL STREET WATERTOWN, MASS

CIRCLE NO. 43 ON INQUIRY CARD

how to conquer space

Compact design of instruments and other precision mechanisms calls for critical evaluation of all components in terms of the *space* they require.

SBB Midget T Series ball bearings can reduce space requirements from 66% to 90% by replacing conventional inch series ball bearings. On basis of ratio of bearing volume to load capacity they are twice as efficient as conventional ball bearings of equivalent bore size. Low torque values, too.

Write today for brochure on Midget T Series.

split ballbearing

A DIVISION OF MPB, INC.

503 Highway Four, Lebanon, N.H.

CIRCLE 44 ON INQUIRY CARD

Silicone Sponge Rubber

for sealing, gasketing, pressure pads, vibration dampening $-100°F$ *to* $480°F$

Low density COHRlastic R-10470 silicone sponge rubber is completely flexible after 72 hrs. at 480°F, shows no brittleness after 5 hrs. at −100°F. High tensile, tear and elongation. Closed cell construction is non-absorbing. Called out on aircraft and electronic drawings and specifications. Available from stock in sheets 1/16" thru 1/2", in rod .180" thru .585". Special extruded shapes made to order.

FREE SAMPLES and folder—write, phone or use inquiry service.

CONNECTICUT HARD RUBBER

NEW HAVEN 9 CHR CONNECTICUT

AIRFRAME SEALS | SILICONE RUBBER COATED FABRICS | SILICONE RUBBER SHEET & SPONGE | MOLDINGS & EXTRUSIONS

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Helical-Geared Speed Reducers

Designed around a single or double reduction helical gearing unit which can be mounted directly on a driven shaft or mounted in standard-stock horizontal or vertical bases, a new series of speed reducers adapts to an unlimited variety of mounting positions. Four sizes of basic units provide output speeds of 10 to 431 rpm, and capacities of 1/6 to 15 hp.

Tradenamed Optimount, the basic units are available in three configurations: Optimount reductors designed for V-belt, sprocket or gear drive to input shaft; Optimount ratiomotors which provide direct motor drive to an input shaft; and Optimount flanged reductors without motor ready for attaching motors of the customer's choice.

In the Optimount basic unit, a machined semi-steel housing encloses the heat-treated alloy steel gearing. Gear shafts which are mounted in ball bearings and double-lipped oil seals for all shaft openings assure extra protection against leakage from within and contamination from without.

Through-bored to permit unrestricted adaptability to mounting conditions, the hollow output shaft adapts to the required machine shaft size with a standard keyed bushing. A standard solid output shaft, required in most base-mounted applications, inserts in the hollow shaft.

An alloy steel input shaft mounts in an end bearing which is locked in place to prevent end-play and the opposite bearing "floats" to accommodate expansion. By removing a cover provided on the back of the housing, a positive backstop may be easily inserted in the unit which will operate instantly to prevent reversal of rotation. Optimount simplifies speed reducer selection by providing standard models from stock to meet any mounting conditions. Boston Gear Works, Quincy, Mass.

CIRCLE 181 ON INQUIRY CARD

or Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

• Capacitance Standards. Ranging from 10 micro-microfarads to 4 microfarads and including variable capacitors ranging from 6 to 230 mmf, a complete line of fixed and variable capacitors for use as precision laboratory reference standards are adjusted to 0.1% and furnished with individual calibration certificates. International Telephone and Telegraph Corp., New York, N.Y. Circle 128.

• Pressure to Frequency Transducer. Basic pressure sensing is accomplished by a variable inductance a-c transducer whose coil is part of an integral oscillator tank circuit. Pressure acting on either or both sides of a diaphragm causes the coil inductance to vary the oscillator frequency which can be pretuned by the factory to any of the 18 RDB sub-carrier telemetering channels from 400 cycles per second to 70 kc per second. Datran Electronics, Manhattan Beach, California. Circle 130.

• Small Motor Shields. New 3-layer Co-Netic Netic small motor shield attenuates magnetic and electrostatic noise radiating from motors used in automatic or programming systems and other small motor applications permitting adjacent components to be placed close to the motor and to function without disturbance from the motor's field. Magnetic Shield Division Perfection Mica Co., Chicago 22, Illinois. Circle 131.

• Rack-Mounted Digital Volt-Ohmmeter. Unit reads d-c volts, a-c volts and resistance, with accuracy of 0.1% on d-c and ohms . . . 1% on a-c from 10 to 1000 volts. Hycon Electronics, Inc., Pasadena, California. Circle 132.

• Reinforced Teflon Parts. Teflon can be blended with reinforcing inorganic additives to increase: resistance to deformation under load by a factor of 10, resistance to wear by rotating shafts by as much as 500 times, stiffness by a factor of 4-5, thermal conductivity by a factor of 5-10, and compressive strength by a factor of 3-4. Chicago Rawhide Manufacturing Co., Chicago, Illinois. Circle 133.

• Electric Monitor. Electric monitoring system detects conditions of voltage, frequency, and phase in any power source, and is capable of operating contactors, switches, alarms, or other devices in response to these variations. Electric Regulator Corporation, Norwalk, Connecticut. Circle 141.

• Voltage References With Low Temperature Coefficients. A low temperature coefficient voltage reference is now available in an axial lead two-watt package. Ideal for limited-space regulator circuits, these units have temperature coefficients as low as 0.001% per degree C and provide a stable reference voltage over the operating range from −55°C to +100°C. Transitron Electronic Corporation, Wakefield, Mass. Circle 142.

• Computer Grade Alumalytic Capacitors. Filter capacitors, designed for use in computer circuits, offer high capacitance per unit of volume throughout wide voltage ranges, and are suitable for operation in ambient temperature of −20C to +65C. General Electric Co., Schenectady 5, N. Y. Circle 144.

• Solid Tantalum Capacitor. A complete line of solid tantalum capacitors that will withstand vibrational acceleration up to 40 g's at frequencies from 5 to 2,000 cycles, and temperatures up to 125 degrees C are made by compressing finely powdered tantalum metal into plugs that are then hermetically sealed in cylindrical metal cans. Absence of a liquid electrolyte eliminates leakage problems, and greatly increases shelf life. Kemet Co., Division Union Carbide Corp., Cleveland, Ohio. Circle 145.

• Environmental Test Instrumentation. Guide for equipment builders and specifying engineers outlines Bristol indicating, recording, programming, and controlling instruments for environmental test equipment. Instruments for measuring, recording, and controlling temperature, humidity, altitude, pressure, flow, and other variables are included in guide. The Bristol Company, Waterbury 20, Connecticut. Circle 147.

• Servo Gearheads. Gearheads for size 11 and 15 BuOrd Servo-motors utilize the differential planetary system, a new application in the servo gearhead field of an old principle, in units having overall lengths of only 0.800 inches. U. S. Gear Corp., Wakefield, Mass. Circle 148.

• Size 8 Motor-Generator. Smallest, highest accelerating Size 8 servomotor-rate generator on the market is an a-c two-phase control component engineered to provide the high torque and low rotor inertia required for rapid, "stiff" response to minimum control signals. Helipot Division, Beckman Instruments Inc., Newport Beach, Calif. Circle 149.

• Miniature Meters and Rotary Switches. Folder contains 22 engineering data sheets which illustrate and describe miniature meters and rotary switches that are bringing to testing, quality control and other industrial instrumentation, new standards of compactness, portability and versatility. International Instruments Inc., New Haven 15, Conn. Circle 152.

• VectroL Packaged Thyratron Grid Control. Thyratrons provide the most economical power regulation up to 30 kilowatts. One VecTroL unit will control 1 half wave or 2 full wave thyratrons. VecTroL Engineering, Inc., Stamford, Connecticut. Circle 153.

• Potentiometer Data. Precision potentiometers, incremental stepping motors and synchros, and pressure switches are detailed and photographs of all the instruments are shown, along with brief construction, performance, and environmental specifications. G. M. Giannini & Co., Inc., Pasadena 1, California. Circle 154.

• Digital Magnetic-Tape Recorder Reproducer. Features: all transistorized electronics, stop and start time less than 3 milliseconds, all-metal-surface magnetic heads, accepts tape widths from 1/2" to 1", uses 10 1/2" NARTB reels and employs continuous-duty servo motors. Datatape Division, Consolidated Electrodynamics Corp., Pasadena, California. Circle 155.

• Airborne Magnetic-Tape Recorder. Operates under high-altitude/high-temperature conditions (To 100,000 feet and 100°C), and features switch selection of all six tape speeds (1 7/8 to 60 ips), downstream monitoring, 7-or 14-track operation, all-metal-surface magnetic record & reproduce heads, and use of 10 1/2-inch NARTB reels. Datatape Division, Consolidated Electrodynamics, Pasadena, California. Circle 156.

SEE US AT WESCON!
Booth Nos. 749-750

CLIFTON PRECISION *can give you what you want in* PRECISION COMPUTING RESOLVERS

Size 8
Wt.: 32 grams
Diam.: .750 in.

Size 11
Wt.: 90 grams
Diam.: 1.062 ins.

Size 15
Wt.: 160 grams
Diam.: 1.437 ins.

ACCURACY

Without any compensation or balancing, 60% of a recent production run of our precision computing resolvers showed functional errors of under .03%. Ninety-five percent of the units showed under .06% error.

Perpendicularity of axes is held to one minute of error in 90 degrees, or ±3′ on the full circle. Due to extreme symmetry of rotor and stator, nulls are excellent. Low phase shifts are an added feature.

VERSATILITY

Many types of Clifton Precision computing resolvers are offered including:

- *Sizes 8, 11 and 15*
- *Stainless steel housing and bearings (corrosion resistant) optional*
- *450°F High Temperature Units*
- *The following compensation available in any or all units:*
  - *Resistive*
  - *Feedback Winding*
  - *Thermistor*
- *Units suitable for use with transistors*
- *Pin or screw terminals or lead wires*
- *BuOrd type shafts available*
- *BuOrd MK 4 Mod 0 brush block configuration available*

PRICE AND DELIVERY

Rotary Components are our business. We have studied the efficient manufacture of synchros and resolvers for many years —with results that have enabled us to lower traditional prices substantially in the past. We ask you to review what you are paying for precision computing resolvers.

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ELECTROMECHANICAL
components & systems DESIGN

OCTOBER 1958

6 OCT 13 1958
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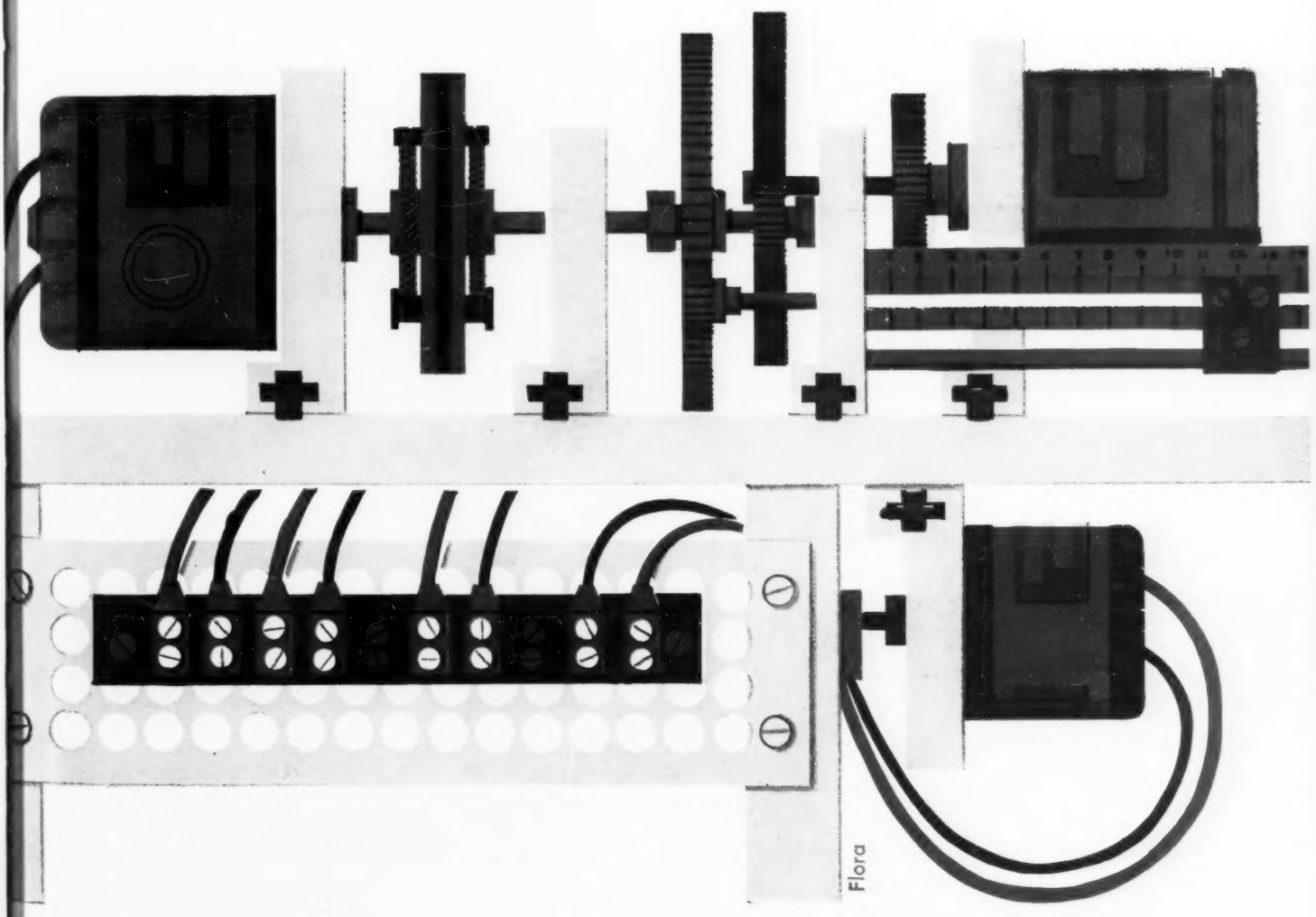
Starting with this issue

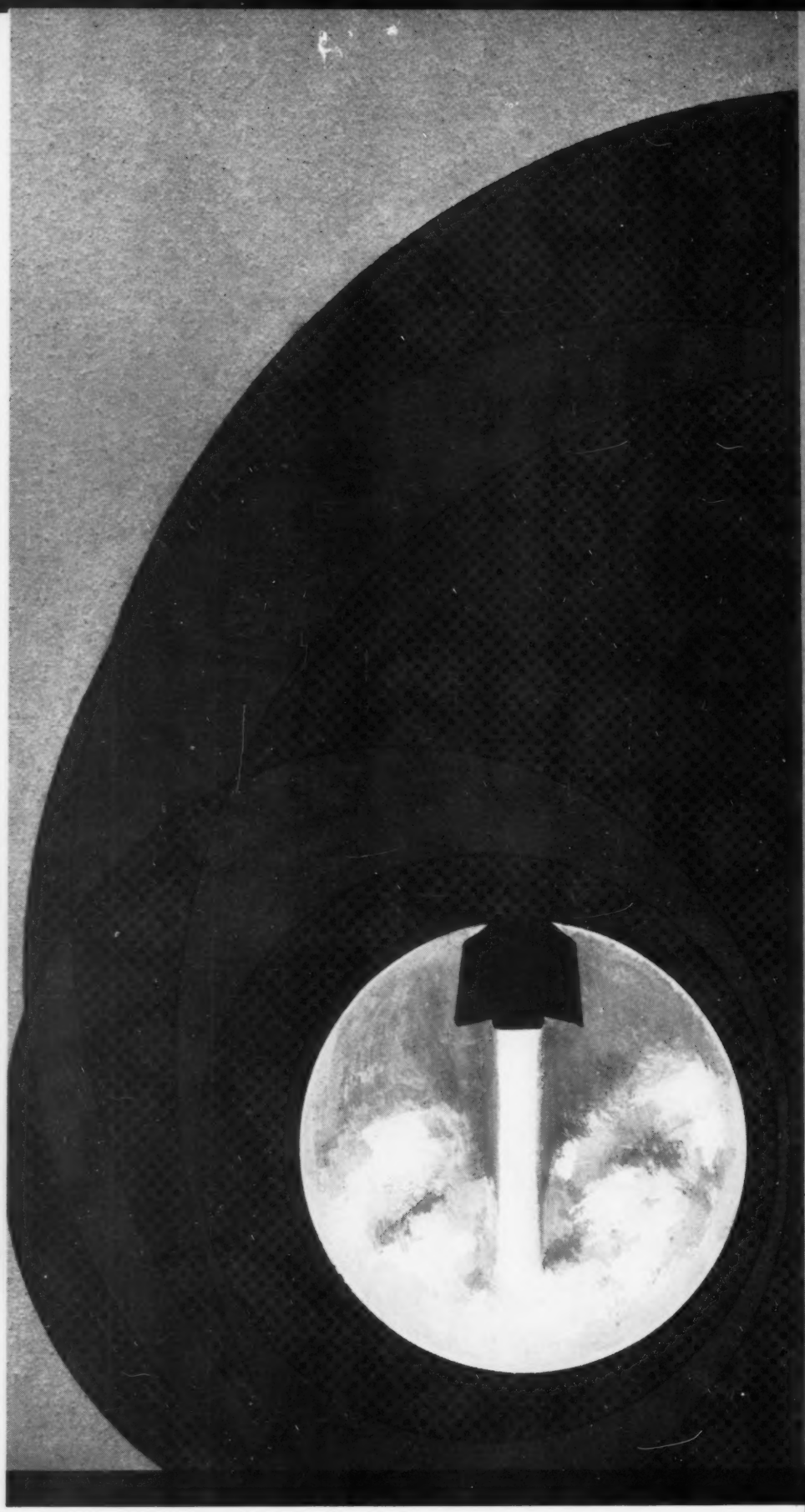
First of a series

COMPONENTS DIGEST No. 1

"Instrument Servo Motors"



Flora



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Avco

Research and Advanced Development division

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OCTOBER 1958
VOLUME 2 • NUMBER 8

ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas and Techniques in Applied Electromechanics

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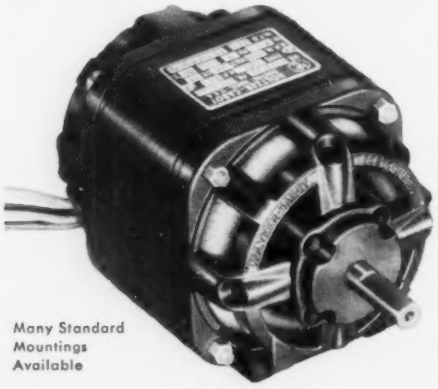
New Designs in Motors from HOLTZER-CABOT



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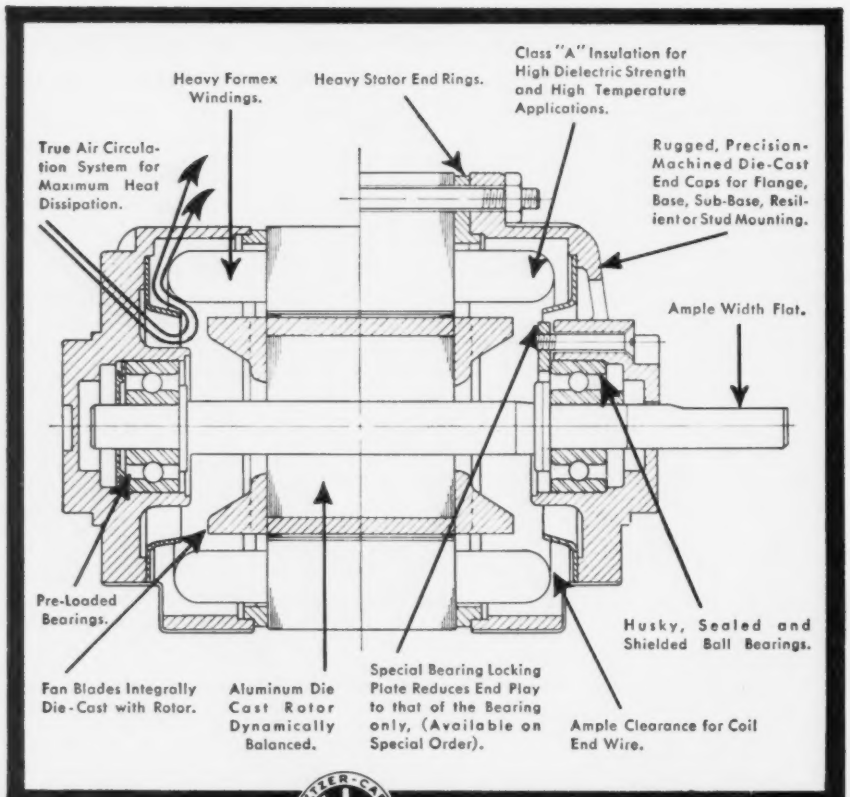
2⅞" Diameter

This motor is an ideal power source for recording instruments, timers, medical instruments, office equipment, blowers, tape recorders, communications equipment, etc. It is available in both 2-pole and 4-pole design, each in three stacking lengths. Type R-29 is a permanent split capacitor type available as an induction or synchronous motor. H.P. of various models ranges from 1/75 to 1/30. Construction features are indicated below.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CIRCLE NO. 7 ON INQUIRY CARD

PROBLEMS NEEDING SOLUTION

Newark, N.J.

In the July issue of ELECTRO-MECHANICAL DESIGN you had a very interesting editorial regarding problems in need of solution. One of these problems had to do with measurements in the microwave field.

. . . Weston Instrument Division of Daystrom has a partial solution to the problem. . . This device, which is a self-balancing bolometric bridge, was originally developed by Dr. Glenn Engen of the National Bureau of Standards, and is now being commercialized by us.

E.G. Nichols
Product Line Sales Manager
Weston Instruments
Div. of Daystrom, Inc.

For more information on this microwave wattmeter circle no. 72 on inquiry card.

. . .

VALUE ENGINEERING

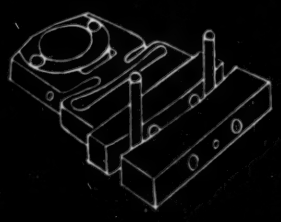
Wayland, Mass.

. . . I make the following comments in connection with the editorial "Components Digest". Performance characteristics are not the only criteria for determining the right component to do the job. The value of the component, i.e., the relationship of its cost to the worth of the function it performs, is also an important criterion. Engineers have in general a greater awareness of electrical and mechanical characteristics than of value characteristics. With this in mind, a useful adjunct to the "Components Digest" could be developed, through the use of Value Engineering techniques, for the purpose of showing the relative value of specific components for various functional applications.

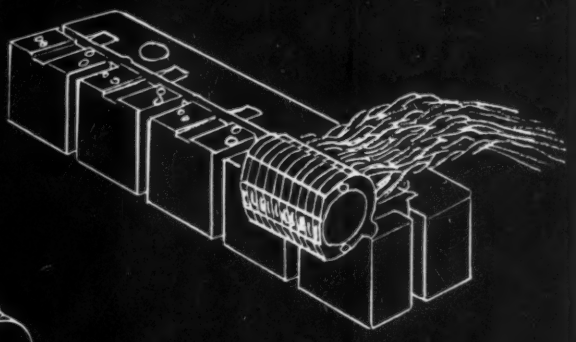
. . . Is gambling the product cost a lesser risk for the engineer and his employer than gambling with the product performance?

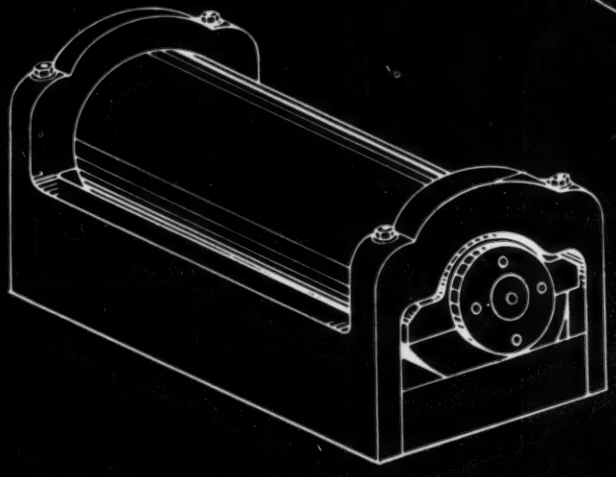
H.B. Macomber,
Value Engineering
Raytheon Manufacturing Co.
Wayland Laboratory

Relationship of cost of a component to the value of its function in an application is certainly an important criterion in component selection. Unfortunately, we cannot anticipate the many ways a given component type will be applied or tried.



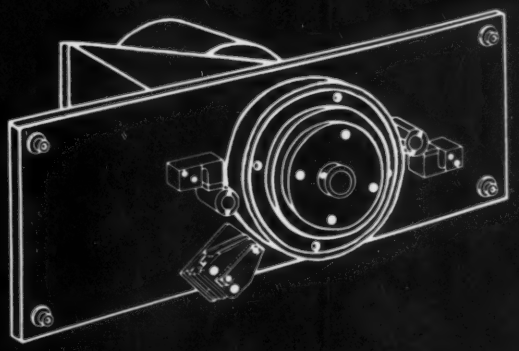
Here are High Performance Components at Budget Prices





Every project engineer can now afford to have his own magnetic storage drum . . . a truly versatile memory system . . . to expedite many jobs. Costing less than the price of a good oscilloscope, a Monrobot modular storage unit offers high performance characteristics with near custom-designed flexibility. Drum speed and head layout may be selected by the systems engineer to meet his individual requirements; belt drive models and open head mounting allow field alteration to accommodate major system changes which require different speeds or delay times. Thus, engineers can "prove out" logic without risk of obsoleting the drum before the system is complete.

Both drums and heads have shown high mechanical stability under rough field conditions and over a wide range of temperatures. The drums, offering information storage at a high density, are rigid and stable with a minimum of run-out. The read/record heads feature built-in fine calibration adjustments and can be adjusted over a delay of forty pulses while the drum is rotating. For complete specifications, write: Monroe, Dept. E, Orange, N. J.



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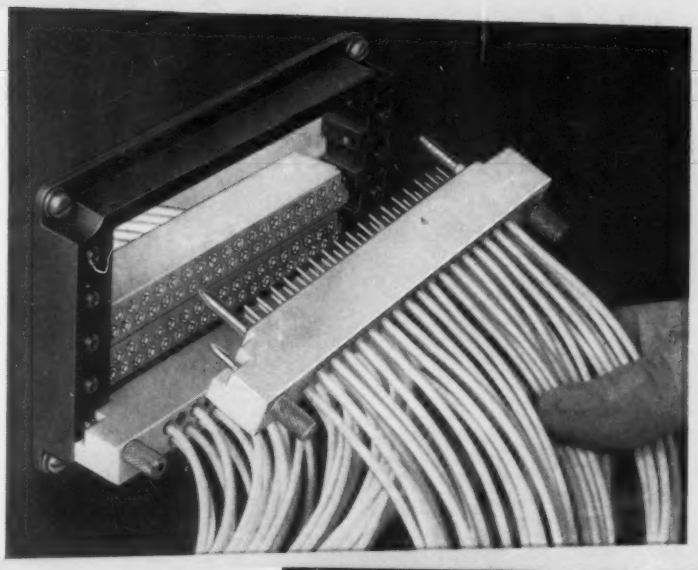
connector

with crimp-type, snap-locked contacts

Makes possible the design of lighter and more compact equipment. Each insert holds 35 contacts. Frames available for 5 or 8 inserts.



crimp-type

MODULAR ELECTRICAL CONNECTORS

IN 3 NEW BASIC TYPES

Modular units by Burndy provide versatile, rapid and reliable answers to the problem of connecting a multiplicity of wires in relatively limited spaces. Crimped contacts—installed with any of several hand, pneumatic, semi-automatic or automatic tools—can be removed, re-inserted or replaced, providing the most complete flexibility in the connector field. Computers, ground-based radar, missile ground controls, and instrumentation are typical applications for Burndy modular connectors.

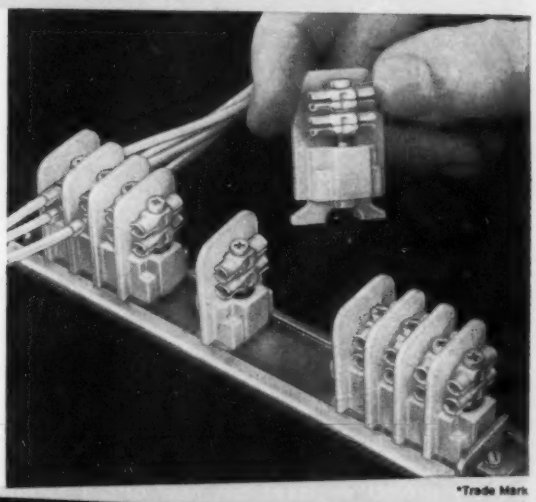
quick-disconnect or permanently connected

MODULOK*

terminal block

with snap-in, spring-loaded contacts

True versatility in a terminal block. 30 modules (2 or 4 tier) per foot. Twist of a screwdriver transforms quick-disconnect contacts to permanent connections.



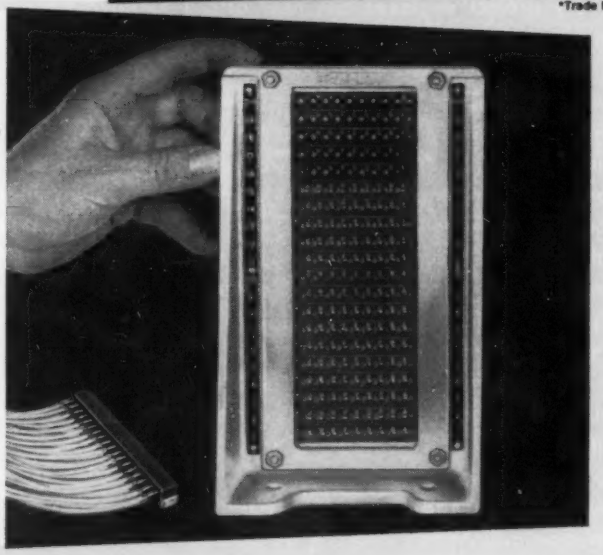
*Trade Mark

crimp-type, solid-shank

STAPIN®

taper pin contacts

Another Burndy contribution to the modular concept of assembling standard units to provide custom-fitted end products.



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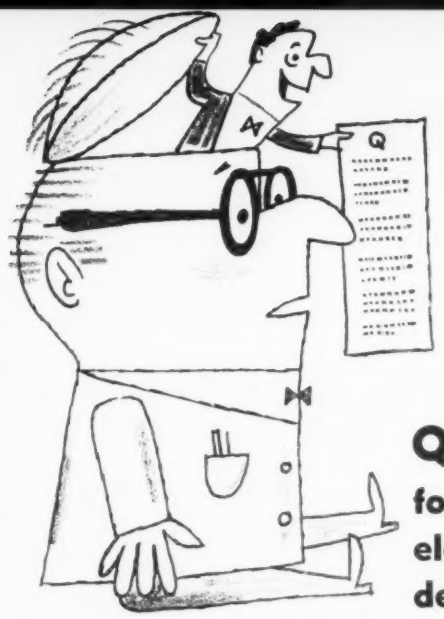

QUESTIONS
for an electromechanical design engineer

1 What are the highest accuracies now available in single or multi-turn potentiometers? What increase can you expect in the near future?

2 *Pot manufacturers have announced accuracies of 0.01 and 0.005 percent in special types. To what extent can these accuracies be maintained in practical military and commercial applications?*

3 What are the maximum temperatures to which you can expose various types of precision pots? What is the life of these units and their degradation at these temperatures assuming negligible dissipation? What is their independent linearity?

4 *What factors affect the performance of precision wire wound pots with use? What special types are particularly resistant to destructive forces in the environments to which they may be subjected?*

5 What are the prevalent commercial and military standards for precision pots?

6 *What is the "effective" resolution of precision carbon pots? of metal film pots? How "infinite" is the "infinite" resolution of these types of pots? How do their resolutions and independent linearity compare with conventional wire wound pots?*

7 What precautions must the application engineer heed when selecting given types of pots for specific applications?

8 *What is the smallest of each type of pot commercially available and what are the practical limits of their performance characteristics?*

9 What's the next biggest improvement in resistance pots, particularly with respect to performance characteristic?

10 *What are some types of unusual pots for special applications?*

ANSWERS

Don't miss the December issue of Electromechanical Design. It will feature Components Design #2 and will be devoted to a definitive roundup of potentiometer information. You'll find answers to all of the above questions plus the hundreds of others that confront you daily.

It's an issue you'll want for your files.

DEC. 1958

ELECTROMECHANICAL
components & systems | **DESIGN**

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DIRECT DRIVE TORQUE MOTORS

D-C Servomotors Provide Efficient Power, Allow High Loop Gain

In stabilization and tracking system servos where size, weight, power requirements and response time must be minimized and where high resolution is desirable, direct drive d-c torque motors have proven to have many inherent advantages.

Chief among these is their high-torque to output inertia ratio. For example, a stabilization problem requiring a peak torque of 60 oz-in could use an Inland direct-drive torque motor that has a torque to inertia of 5350 rad/sec^2. A gear train servo motor for the same requirement would have a torque to inertia ratio at the output shaft of only 1/10 this value or less. Typical performance curves for some of Inland's motors are shown in the accompanying figures.

Other important advantages result from the direct drive characteristic. Absence of backlash effects in servos with direct drive torquers together with absence of any measurable ripple effects in the motor itself, except at very high torque levels, allows use of high-loop gain to obtain fast servo response time and ideal resolution. In stabilization systems with direct drive, error is introduced to the stabilized member only through friction, whereas with gear drive, base motion accelerates the motor through the gears thereby adding acceleration error. Gears also greatly increase the friction errors.

Total friction torque of Inland direct drive units is not more than 2 percent of maximum torque. The ratio is even less for large units with peak torque output greater than 3 lb-ft.

A complete line of d-c torque motors ranging from a unit 2 inches in diameter and ½ inch thick, producing 0.1 lb-ft peak torque to units producing over 100 lb-ft peak torque are now standard items at Inland Motor Corporation. Even larger units are available. Inland has on order a unit with peak torque rating of 3000 lb-ft for an antenna-drive application. They are even talking about performance in the realm of 100,000 lb-ft for antennas of the 80 to 100-ft. diameter variety, but they are not sure whether their present design approach will be adequate for this performance.

In our January-February issue we discussed the theoretical advantages of using direct drive torque motors in stabilization systems and described the excellent performance achieved by Detroit Controls of Norwood, Mass. in such an application. As a result of this article many readers have requested information on the torque motors that make this performance possible. Here then are important performance characteristics and design details of these motors made by Inland Motor Corporation, Pearl River, N.Y.

WHY D-C TORQUERS?

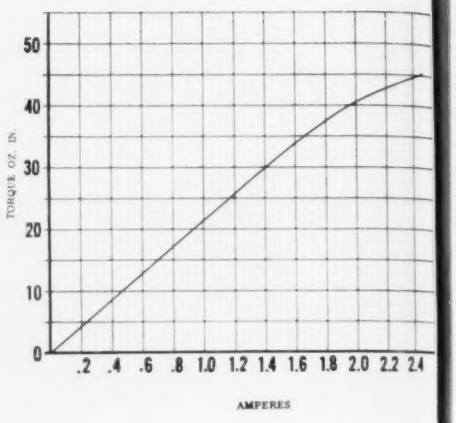
Inland chose d-c rather than a-c torquers for direct drive applications because d-c units require substantially less input power to obtain a given torque, much smaller size for a given maximum torque, and can have a faster torque vs time response. High-level saturation of the rotor core by the permanent magnet field and use of a maximum number of poles can reduce control winding self inductance to negligible levels.

SPEED OF OPERATION

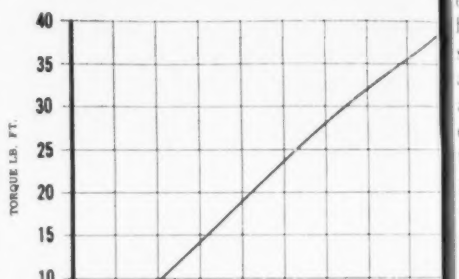
Inland torque motors are designed for essentially stand still operation. However, speeds up to 100 rpm rarely present difficulty. Speed is limited by the voltage between one commutator bar and the next when the current is being reversed by commutation.

This limiting voltage is a function of the amount of iron in the circuit, number of coil turns, speed of rotation and resistance of the brush. Generally, the higher the resistance of the brush the better the commutation, but there is a limit to the brush resistance that can be tolerated in servo applications because higher resistance adds resistance uncertainty in the loop. Increasing the number of commutator bars so that the number of turns between bars is decreased also improves commutation.

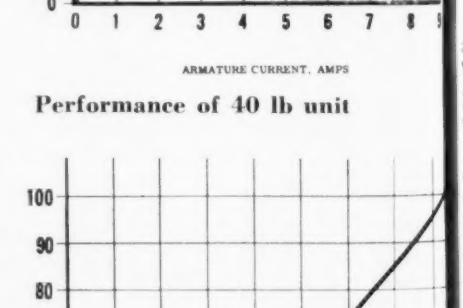
When you have used the maximum number of bars that can be fitted in the alloted space and brushes with the maximum resistance that can be tol-



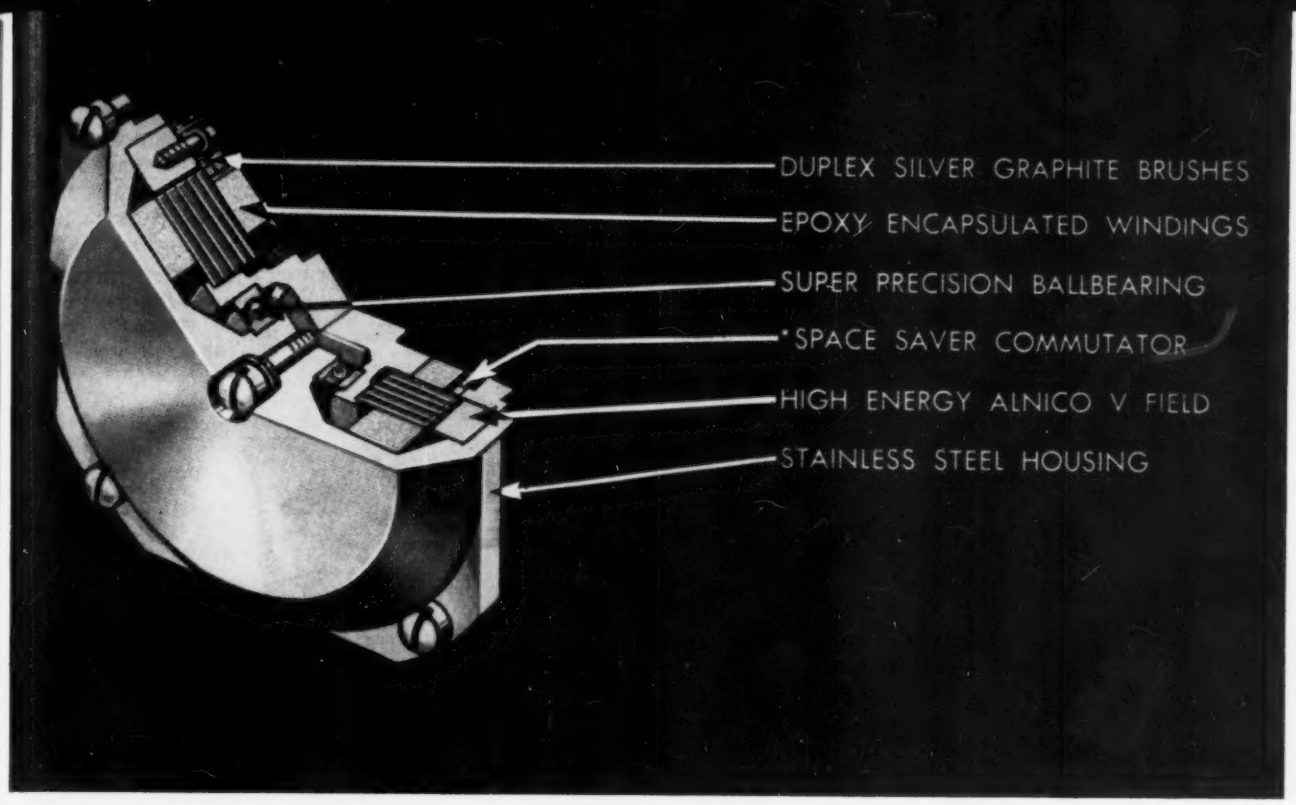
Performance of 9 ounce unit



Performance of 40 lb unit



Performance of 110 lb unit



erated, you can't increase the speed further without derating torque. Very small units, such as Inland's 2-in diameter design can run intermittently at speeds of several thousand rpm operated at less than peak torque and up to one thousand rpm intermittently at peak torque. Speed limits of larger units are considerably less. For example, speeds in the region of 500 rpm are beyond reach of Inland's 10 or 20 ft-lb standard units.

MOTOR CONTROL POWER

Specially designed rotary amplifiers are generally used to drive the torquers. With good design they can be made to provide very fast response consistent with that of torquers.

Vacuum tube drives provide the fastest type of control. They have the disadvantages associated with relatively high power electronic systems, however. These problems are being sidestepped in some cases with use of high power transistors as switches in a high frequency pulse-width-type amplifier. So far, however, these transistor units are limited to use with the smaller torquers.

TORQUER DESIGN

The first direct-drive torquers made by Inland were designed for stabilization systems. Since the torquers were to mount directly on the stabilization gimbals where space and weight are severe limitations, a major objective was to make them as small as possible. The major problem to be solved was ripple—the torquers were not even feasible if their torque varied substantially with rotation. Inland engineers knew that a skewed rotor with the proper proportion of slots to the number of stator slots would minimize ripple. The difficult aspect of the problem was to accomplish this in a minimum sized unit.

Inland reduced the size of the rotor by mounting the commutator directly on the winding. The commutator bars actually went through the slots. After the bars were connected to the windings the whole rotor was encapsulated. The commutator ended up taking no appreciable space beyond that of the wound core, except for the insulation of the bars. The bar arrangement appears to be something like that of a variac where the windings have been turned away. Inland doesn't turn away the windings, however. They simply add more bars and connect the windings to them.

Inland also saved space in the stator. Normally field poles in d-c machines have substantial tooth tips to the pole face and, to achieve a low speed voltage in the commutated coils, the space between the poles is relatively large both circumferentially and radially. By using Alnico-V magnets in the field, Inland was able to eliminate the slots and the spaces between the poles in the field. Simply having a highly saturated bridge of magnetic material going from one pole to the next resulted in a reduction in outside diameter of the field assembly without sacrificing anything to the ripple problems: there were no slots on the inside of the field that could conspire with the rotor slots to cause ripple.

The very thin bridge that connects one pole to the next is of course thoroughly saturated by the permanent magnet field, but the amount of flux through this path is relatively slight.

The combination of these rotor and stator designs and a rather simple, small brush rigging made possible by the commutator configuration resulted in a much smaller torque motor than any Inland had seen before. Furthermore, the stator is very simple and easy to produce and no complex skewing for either the stator or the rotor is required. Best of all, ripple effects are negligible. There is no measurable reluctance torque effect with rotation and no change in the per ampere sensitivity with rotation. However, there is a slight change in input resistance as the brushes move from bar to bar resulting in a small variation in per volt sensitivity, and armature reaction causes an additional ripple at very high torque levels. But these effects have had no visible effects in system applications.

Circle No. 62 on Inquiry Card

Ferrite Data File

New loose-leaf file-type catalog covering Microwave Ferrite Components contains a series of eight preliminary data sheets and engineering bulletins on advance models of load isolators, circulators, and deplexer switches recently introduced. This publication will be kept current as new devices are announced. It complements and expands upon a short-form catalog used for brief and rapid reference.

Source: Cascade Research
Los Gatos, California

For your copy: Circle No. 186 on Inquiry Card

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

types: ALL INSULATIONS
including polyvinyl chloride; asbestos; silicone rubber; Teflon; Kel-F; polyethylene; Nylon; etc.

conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

source: CONTINENTAL WIRE CORPORATION

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CIRCLE NO. 5 ON INQUIRY CARD

One House for Eight Speed Switches

Up to eight separate speed sensing switches can be incorporated into a compact housing developed by Torq Engineered Products, Inc. Each speed switch in the housing controls one circuit, which can be actuated by a high speed limit and a low speed limit.

A typical example of use is for diesel engine control. In addition, this multi-speed switch is suited for control of multiple speeds on machine tools, control of inter-related speeds in automated systems, synchronization of separate drives on large printing presses and similar equipment, and for actuating various aircraft and missile circuits which can be controlled as a function of speed.

The individual Syncro-Snap speed sensing switches require a rapidly decreasing rate of pressure at the critical switching point. This feature, combined with rapidly increasing centrifugal force, results in a positive snap action, eliminating any tendency to "flutter" or "chatter." The action of these switches is determined by speed alone, regardless of voltage or load. Accuracy is to ¼ of 1%, and life expectancy is 1.5 to 3 million cycles, with no signs of frictional wear and no variance in operational characteristic. Torq Engineered Products, Inc., Bedford, Ohio.

Circle No. 97 on Inquiry Card

Miniaturized Magnetic Switch

New miniaturized, magnet-operated, capillary contact permits operation of a new switch even when tilted as much as 45° from vertical. Metallic-end caps seal the cylindrical glass envelope so that the operating parts and the mercury are maintained in a hermetically sealed enclosure. Movable contact in the switch makes contact with the mercury by penetrating an opening in the capillary tube. The capillary tube is positioned so as to be supplied by the mercury in the well.

These switches are adaptable to applications where a mechanical movement of approximately 0.032″ with a force of two grams is available to move the permanent magnet—such as in recorders, gauges, scales, etc. The switches can also be operated by small d.c. electro-magnets for incorporation in electrical or electronic equipment. Electrical connections to the switch are made thru the metallic-end caps, eliminating lead wires attached directly to the switch.

Two types are available: Type 6-81 normally open and Type 6-83 normally closed. Electrical rating: 115 volts a-c 0.3 amp, d-c 15 amps; 230 volts a-c 0.15 amp, d-c 0.7 amp; 24 volts a-c 0.9 amp. Dimensions: Overall length 1½″; outside diameter of metal caps ⅜″. Approximate weight 0.15 oz. Mercoid Corporation, Chicago, Illinois.

Circle No. 166 on Inquiry Card.

5,000-volt Glow Discharge Unit

Capable of delivering 400 ma at a full 5000 volts d-c, the highest-powered glow discharge unit on the market can efficiently bombard more pieces, at a greater distance, and at a lower pressure than smaller units. Because of its higher accelerating voltage, the unit will bombard a surface with a higher than usual velocity resulting in a cleaner surface for coating. Removal of the last mono-molecular film, which clings to the cleaned surface of a piece to be coated, provides better adhesion of the deposited films.

Two ½-inch NPT-tapped holes for the two electrodes are required for installation. The circuit is designed around a hi-reactance transformer which automatically limits the current in the secondary of the transformer. Under maximum load conditions, this transformer delivers approximately 90% of the input power, a decided advantage over ballast resistors which consume up to 30% of this power. Consolidated Electrodynamics Corp., Pasadena, Calif.

Circle No. 92 on Inquiry Card

Peanut Switch

Sub-miniature basic switch has a 2½ million cycle mechanical life, longer electrical life than switches twice its size, no dead break for perfect, sensitive application and high repeatability with only one moving part besides button. The unit mounts with consistently close tolerances in single or ganged setups. It may be procured with any of the usual types of standard actuators. Simplified ganging is achieved by using a No. 1 screw bolt (0.075″ max.) which passes through in-line holes in the switches provided for this purpose. Switch Division, Electrosnap Corp., Chicago, Illinois.

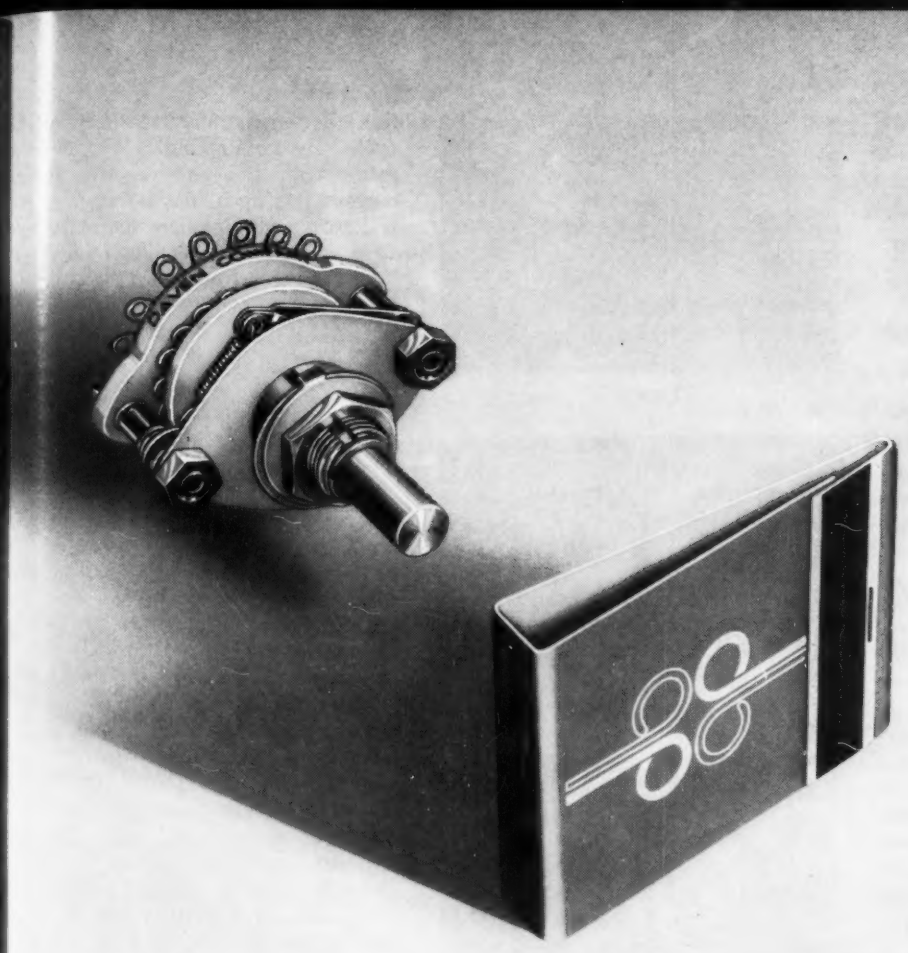
Circle No. 170 on Inquiry Card

Mach Charts

Two mach charts are part of reference data that appears regularly in the "Giannini Technical Notes." One chart compares mach number with altitude, and also gives the ram temperature rise. The second chart shows the relationship between mach number and temperature.

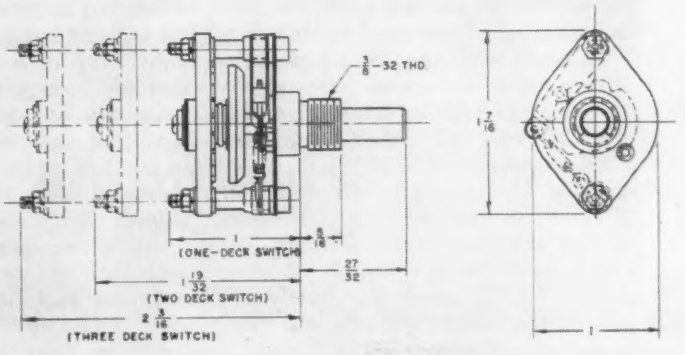
Source: G. M. Giannini and Company
Pasadena, California

For your copy: Circle No. 189 on Inquiry Card



DID YOU SAY | small? |

Occupying less than 1½ square inches of panel space, this Miniature Ceramic Switch nevertheless contains as many as **18 positions on a single wafer.** And it's rugged! Solid silver alloy contacts, rotors, and slip rings provide low and uniform contact resistance. Ceramic parts are silicone impregnated to function under extreme humidity. Sturdy solder terminals are supplied for wiring. This miniature switch meets and exceeds the electrical and environmental requirements of Mil-Spec S-3786. Flashover voltage at 60 cycles is 1000 volts peak . . . current carrying capacity is 2 amperes. For guided missiles, airborne radar equipment, portable and mobile ground equipment . . . for any application that requires an extremely small and rugged switch, specify Daven's Series M Miniature Ceramic Switches. These units can be "ganged" with up to 8 decks with slight mechanical modifications. 2 or 3 poles per deck may also be obtained as standard. Prototypes can be delivered within 2 weeks.



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SERVO MOTOR WINDINGS FOR TRANSISTOR AMPLIFIER DRIVE

How to Eliminate Amplifier Output Transformer

Frank E. Hagen, Proj. Eng.
Daystrom Transicoil Corp.

The demands of the control industry for miniaturization in both military and commercial applications have produced many space saving techniques: reduction of size of control motors and all related components; elimination of some seemingly necessary components, such as the output transformer from electronic control amplifiers.

The output transformer coupled a push-pull output stage of an electronic amplifier to the two-lead control winding of the servo motor. It, also, was selected to match the output impedance of the amplifier with the control winding impedance of the motor. Removal of the output transformer left a gap in both of these functions. This problem was solved by providing a center tap on the control phase winding; inserting the amplifier "B" supply at the center tap; and connecting the two ends of the control phase winding to the plates of the push-pull amplifier. The motor winding itself replaced the transformer primary. Since no means were available to adjust for matched impedance, the motor manufacturers constructed the motor winding impedance equal to the amplifier output impedance and finally settled on a standard control winding impedance of approximately 9000 ohms so that the control industry could buy equivalent motors from more than one source.

Since transistors now replace control amplifiers, a new standard control winding is necessary. The method utilized in vacuum tube amplifiers for the elimination of output transformers still holds for transistor output stages. Only the parameters governing the selection of a standard control winding differ.

To begin with, the "B" supply voltages common in vacuum tube circuits are much too high for transistor operation. Virtually all power transistors, whether germanium or silicon, are now designed for operation with a 28 volt "B" supply. Assume the transistors feeding a motor control winding, operated as a perfect switch, flipping the 28 volt "B" supply first across one side of the motor winding and then the other as shown in Fig 1.

Fig. 2 shows the waveform across the entire control phase of the motor.

The Fourier series of sine waves of this control phase voltage is:

$$e_c = 71.3 \cos\omega t - 23.8 \cos 3\omega t + 14.2 \cos 5\omega t - 10.2 \cos 7\omega t \ldots \text{etc.}$$

The maximum possible fundamental rms voltage available from a 28 volt "B" supply is then $71.3/\sqrt{2}$ or 50.4 volts. This signal, of course, would carry with it the high odd harmonic distortion shown in the Fourier series. If you wanted to establish a control phase voltage completely free of harmonics, from the same "B" supply, the voltage would be evolved from a condition similar to that shown in Fig 3.

Fig 3 shows that the maximum possible undistorted voltage which can be applied across the motor under ideal conditions is 56 cosωt. The fundamental voltage has an rms value of 39.6 volts. Both of these conditions assume that the voltage drop across the transistor can be adjusted to zero.

In the case of certain germanium power transistors this is virtually true. However these same germanium transistors, with extremely low saturation resistance, require a resistance in series with their emitter. This series emitter resistance performs two functions. The most important task is to prevent the transistor from destroying itself. At higher junction temperatures the transistor leakage current begins to increase. As it increases, it further heats the junction thereby creating a vicious cycle. By connecting a resistance in series with the emitter, this leakage current sets up a bias between emitter and base and minimizes its own effect. This resistor also introduces a degenerative effect on the output circuit which minimizes the effect of parameter variation with temperature.

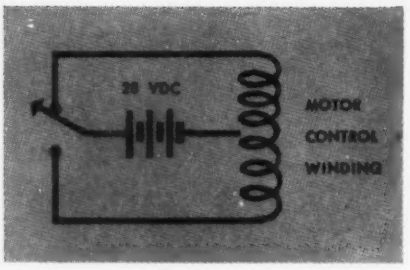

Figure 1

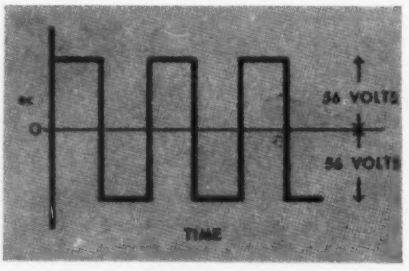

Figure 2

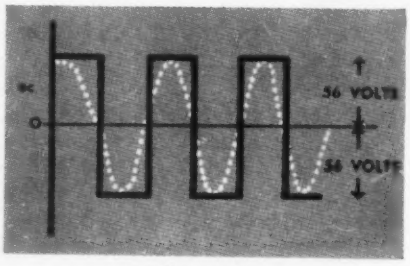

Figure 3

A good practical value for this resistor is 5 to 10 ohms. Placing a resistor of this type in series with each of the power transistors effectively decreases the "B" supply. If an output stage is designed to drive a size 15 motor and the emitter resistors used are 10 ohms each, the maximum undistorted fundamental available is 41.4 volts. However, this latter figure is unrealistic. It is virtually impossible to develop a signal on the power transistors' bases to produce such a waveform.

A maximum voltage of 38 volts is more realistic. However, if the motor is wound for 38 volts, it takes an extremely high error signal, far beyond the realm of linear amplifier, before the motor develops full torque. A more optimized winding voltage for such a motor is 35 volts. Here a voltage relatively free of distortion can be developed across the control field when the error signal has just left the linearity region of the amplifier.

This discussion in no way means to imply that other winding voltages are wrong. Full power may be developed across windings up to 38 volts even though the amplifier has saturated far below this figure. In fact higher voltages may be developed at the expense of transistor stability. In the other direction, control windings far below 35 volts may be utilized. However in these cases the amplifier efficiency is greatly lowered as much higher d-c currents drains are required from the same 28 volt "B" supply.

If a circuit is designed around silicon power transistors, approximately the same solution results. Silicon power transistors have much higher saturation resistances than germanium. However no stabilizing emitter resistors are required.

With a 35 volt winding established as the theoretically optimum value, it was necessary to design an entire line of motor windings closely approximating this figure. The design considerations preventing this exact value were the desire to keep the same copper to iron ratio in each motor and the unavailability of fractional wire sizes. For size 8 and 9 motors, where lowered power supply efficiency is not an important factor, 33 volt windings were standardized. The winding selected for size 11 motors and all higher powered units was 36 volts.

Circle No. 55 on Inquiry Card

COMPONENTS

Rugged Image Orthicon Tube

A new rugged image orthicon tube for military, industrial and scientific applications will withstand extreme environmental conditions of shock, vibration, temperature and humidity. The tube operates throughout the range of vibration specified in MIL-E-5272A, which demands 10 G's acceleration up to 500 cps. At 5 G's acceleration (50 to 500 cps), the tube shows horizontal resolution of at least 350 lines with 3×10^{-2} foot-candles illumination on the photocathode. Thirty G's shock does not impair tube performance. WL-7198 is a very sensitive tube. At least 250 lines horizontal resolution may be obtained with only 0.0003 foot candles illumination on the photocathode of the tube. Westinghouse Electronic Tube Division, Elmira, New York.

Circle No. 164 on Inquiry Card.

WORTH FILING

Mica Capacitor Reliability Study

Six-page two-color folder, entitled "Reliability Study of Silvered Mica Capacitors . . . and How Debugging Assures Greatest Dependability and Longest Life", discuses relationships among the various sizes and comparison between dipped mica and molded mica capacitors, the effect of voltage and temperature stress on life and the advantages of "debugging" operations in increasing reliability of mica capacitors. Folder also includes the expected per cent failure for "debugged" and "undebugged" capacitors and a number of "Shape of Failure Curves" charts.

Source: Electro Motive Manufacturing Co. Willimantic, Conn.

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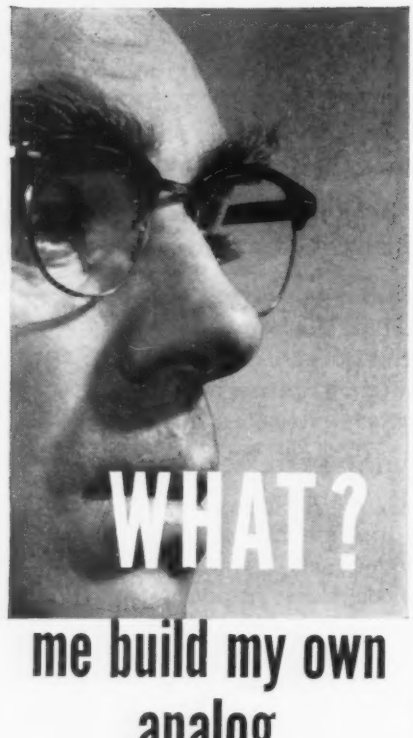

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COMPONENTS

High-Speed Switch Readout Counter

A 40-count-per-second, 5 digit readout counter with a life of over 300,000,000 counts has been designed by Telecomputing Corporation.

The electro-mechanical counter is intended for military and industrial high vibration and extreme G-load applications. A unique bidirectional stepping mechanism for adding and subtracting will not double-index during shock, vibration or voltage surges. The counters are rapid-follow digital function indicators to provide position of almost any discrete variable or for storing in-out information for tabulation.

Switch readout is an etched 10-point switch and circuit combination that makes each point on the switch externally available. An available preset wheel bank provides manual preset to a desired count to actuate an external circuit.

A merchanical push bar for single-stroke reset to zero, or a remote switch electrical reset are available. Models are available to 24, 90, or 110 volts d-c or to specification. The digits are 3/16″ high. Telecomputing Corp., Data Instruments Div., North Hollywood, Calif.

Circle No. 77 on Inquiry Card

Miniature Magnetic Clutches

Miniature magnetic clutches specially designed for military or commercial control applications are available in double ended models with either servo or flange type mounting surfaces. Performance characteristics include fast response and torque values up to 100 inches-oz with 0 torque in completely disengaged position.

Engagement can be accomplished without axial movement of either input or output shaft. Designs are adaptable to high vibration and shock conditions. Sizes ½″ to 3″ diameter. The MagneTec Corporation, Los Angeles, California.

Circle No. 76 on Inquiry Card

Rotary Switch

New, compact type JL rotary multipole switch has a maximum of eight contact positions and up to ten sections controlled by a single knob. The type JL meets BuShips drawing 9000-S6 202-74422, with 3, 5, or 10 sections; a modified type JL can be furnished with any number of sections, up to ten. Electrical rating is 5 amperes 125 volts a-c.

Each section of the switch contains a rotor with a movable contact that engages stationary terminals inside the insulating walls of a molded disk. Rotor movement can be unlimited in either direction, or limited to any number of the eight positions by placement of two stop screws in the rear plate of the switch. Electro Switch Corp., Weymouth 88, Mass.

Circle No. 124 on Inquiry Card

Airborne Binary Shaft Encoder

Special logic used in Norden ADC-BNRY shaft encoders automatically performs brush selection within the encoder eliminating electronics otherwise required for double brush V-scan systems. Digit and complement are simultaneously available in unambiguous natural binary. Novel design provides exceptionally long noise free life by preventing commutation of load currents on the disk, yet allowing continuous or pulse reading at up to 200 rpm. A simple error detecting scheme provides a means of detecting and rejecting erroneous readings. Designed for airborne use, the encoders are believed to be the smallest available in spite of extra capability. Norden, Division of United Aircraft Corporation, Milford, Connecticut.

Circle No. 165 on Inquiry Card.

Electronic Relay

New electronic relay is used in conjunction with 25,000 ohm to 1½ megohm resistive type photo-electric scanning heads for such applications as monitoring, filling, counting, detecting, registration, and inspection. The relay and scanners respond to light changes from a direct or reflected beam. Small signal changes are amplified electronically to provide positive relay operation. Unit comprises an enclosed, plug-in relay, a potentiometer, a power supply for external light source, and circuitry. Power consumption is 9 watts; power source is 100-130 volts, 50/60 cycles.

Relay contacts are double-pole double-throw, 8 ampere 115 volts a-c, non-inductive. The relay can also be used with variable-resistance transducers, providing electronic amplification of low-energy signals. Farmer Electric Products Co., Inc., Newton Lower Falls, Mass.

Circle No. 69 on Inquiry Card

Hi-temp 2-Watt Resistor

Low priced, two-watt film resistor designed for industrial and military applications at temperatures up to 150°C, is being produced in the same size and price range as carbon composition resistors.

The glass-based resistor bears a tin oxide metal film and has a resistance range of 200 ohms to 1.5 megohms. It is capable of withstanding momentary overloads up to 250 times its rated power of 2 watts at 70 C. Operating at a low noise level (0.01 microvolt per volt) the resistor offers higher stability and load life under high humidity than carbon composition resistors.

Maximum resistance change caused by high humidity is one per cent and after one year of shelf life, the maximum resistance change is 0.2 per cent. The color-coded resistor also offers a lower temperature coefficient of resistance (250 PPM maximum), and its voltage coefficient of resistance is practically zero (0.001%/V). Maximum resistance change as a result of normal soldering techniques is 0.5 per cent.

Available in five and ten per cent tolerances, the new Corning resistor has an o.d. of 0.318 inches, is 11/16 inches long and is coated with a high-strength silicone resin film serviceable to 150°C. Like all Corning resistors, it is manufactured by permanently bonding tin oxide to Pyrex brand glass at red heat. Both core and film are impervious to moisture. Corning Glass Works, Corning, New York.

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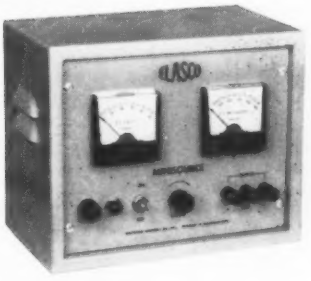

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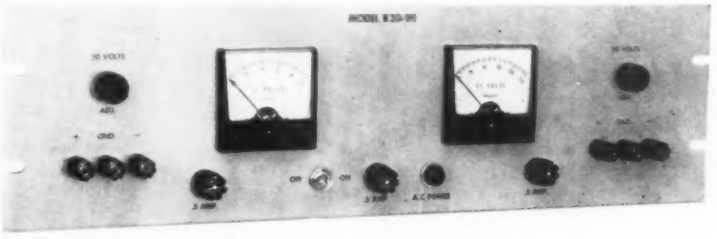

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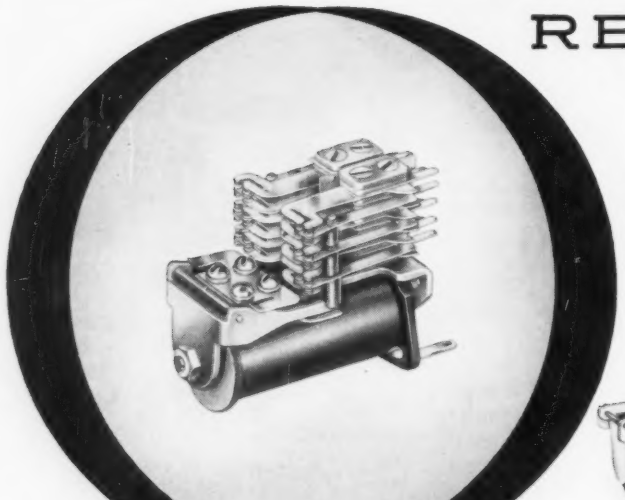
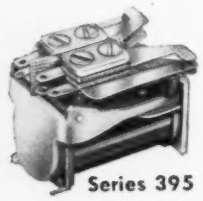
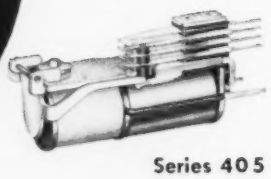


Series 695-T



Series 395



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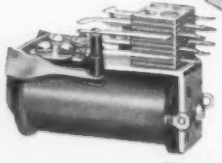
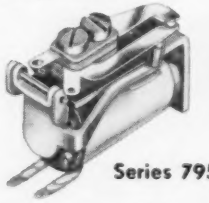


Series 695



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MINIATURE SERVOMOTORS SIMPLIFIED

Solid-magnet stator reduces cost, maintains performance

A radically new development in miniature servo motors replaces the conventional laminated, slotted stator and its complex winding array with a solid magnet structure (molded or cast) and a single bobbin-wound coil per phase. This simple and novel construction increases the possibilities of cost reduction and miniaturization. The manufacturer states that, despite its simplicity, the new motor matches or surpasses the performance and reliability of conventional motors. Designated M-100 (Patent Pending) it was developed by Dynamic Instrument Corp. of Westbury, L. I., N. Y. under study contract from the Bureau of Ordnance to meet all military specifications for motors of its type.

D.I.C. claims the following advantages for the bobbin-wound stator construction:

- It is easily wound with high-temperature insulated wires.
- It allows finer wire sizes than are possible in conventional constructions. Size 50 wire (approximately 1 mil in diameter) or even smaller can be economically handled. This is at least 7 or 8 wire sizes finer than most manufacturers consider practical. It is now possible to wind even the smallest motors for 115 volts, or even higher voltages where required for plate-to-plate operation. This technique frequently eliminates step-down transformers; means smaller tuning and phase-shifting capacitors.
- The problem of dielectric strength is an order of magnitude less critical as a result of the bobbin windings. Not only are dielectric strengths of 2500 volts rms between phases and to ground feasible, but elimination of mechanical stresses and of insulation abrasion also boosts the reliability of the individual phase coils.

The stator of Dynamic's new motor consists of individual phase assemblies. Each assembly consists of a ferromagnetic portion of high-resistivity magnetic material and a coil. The configuration of the former determines the number of poles of the motor. Because the magnetic flux (excepting leakage)

links all the turns of the coil, in contrast to the partial linkages of conventional motors, Dynamic finds that current requirement is reduced, contributing to high efficiency even in small, lower-frequency motors.

Reduction of eddy-current losses in the pole structure is the principal problem in such a design. These losses are held to practical limits by selection of high-resistivity material and optimum design of the circuit geometry. Because eddy-current losses are unimportant in very small motor sizes, Dynamic feels that its motor is particularly suited to miniaturization, providing both higher comparable efficiency and marked economy afforded by the simple construction.

Although a complete line of 60 and 400 cycle motors is still under development, D.I.C. has completed a 4-pole, 115 volt, 60 cycle, size 11 motor in a BuOrd Mk 14 frame. The designers point out that strong viscous damping and low time constant are possible in the new construction. They also emphasize, from the performance characteristics of Fig. 1, that a stall torque of 0.4 oz. in., ample for many applications, is developed with only ½ watt on the control phase. They state that exploiting these characteristics makes it possible to design a servomechanism with no special provision for damping having excellent stability and using only miniature (½ watt) control amplifier.

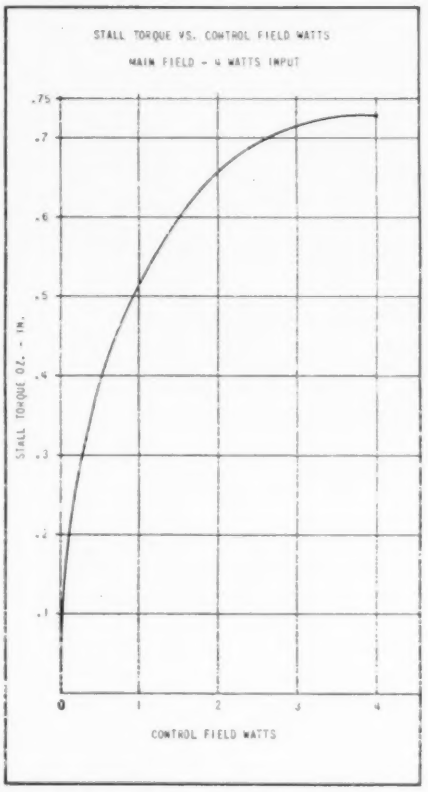
Circle 58 on Inquiry Card

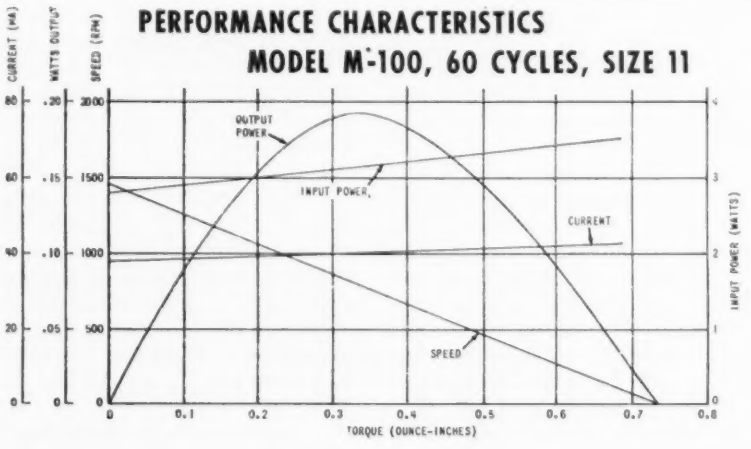
ELECTRICAL DATA

	Size 11	
	Fixed Phase	Control Phase
Voltage	115	115
Current (Stall) – MA	42	42
P.F. (Stall)	.73	.73
Power (Stall) – Watts	3.5	3.5
R (Stall) – Ohms	2000	2000
X (Stall) – Ohms	1900	1900
Z (Stall) – Ohms	2800	2800
Effective R (Stall) – Ohms	3800	3800

MECHANICAL CHARACTERISTICS

	Size 11
Rotor Inertia (gm-cm-²)	1.4
Torque @ Stall (oz. in.)	.73
No Load Speed (rpm)	1450
Time Constant (SEC)	.005
Max. Power Output (Watts)	.18
Torque @ Max. Power Output (oz. in.)	.35
Speed @ Max. Power Output (rpm)	725
Theoretical Stall Acceleration (RAD/SEC²)	35,000
Duty	Continuous
Operating Temperature Range	400°F
Damping (DYNE-CM-SEC)	300





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CIRCLE 11 ON INQUIRY CARD

COMPONENTS

Transistorized Frequency Standard

Transistorized crystal controlled frequency standard designed to meet the most stringent missile requirements, utilizes silicon transistors in a modular construction allowing maximum design flexibility through a wide range of output frequencies and waveshapes. High reliability is attained through use of bistable divider circuits. Frequency stability is ±0.0002% over ambient temperature range of −55°C to +90°C. The standard is hermetically sealed; will withstand shock of 100g; accelerations of 20g or better; and vibration, 10g to 2000 cycles. Total volume of the Standard at 50 cps pulse output is less than 13 cubic inches. Gibbs Manufacturing and Research Corporation, Janesville, Wisconsin.

Circle No. 125 on Inquiry Card

WORTH FILING

High Reliability Resistor Test Brochure

20-page two-color brochure, entitled "Factual Resistor Reliability", describes in detail the non-destructive conditioning and testing procedures used on high reliability precision resistors. Included are complete test specifications covering test procedures and performance requirements on Mepco's encapsulated carbon film and wirewound resistors. Outlining procedures used for temperature cycling, power conditioning, and X-ray inspection, the brochure also contains a section covering the manufacture and physical characteristics of the ceramic core material used by Mepco followed by a detailed discussion of reliability factors in the design of small electronic components.

Source: Mepco, Inc.
Morristown, New Jersey

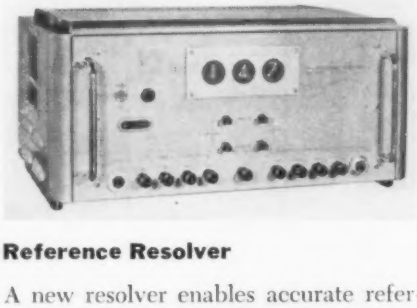
For your copy: Circle No. 116 on Inquiry Card

Adjustable Magnetostrictive Delay Line

A new general-purpose magnetostrictive delay line is characterized by (a) continuous variation of delay rather than step-by-step taps; (b) medium impedance; (c) inherent ruggedness and stability; (d) insensitivity to temperature changes; (e) 50 or 100 ohm coaxial cable connections; and (f) small size considering its range. General applications include use as high access rate temporary storage for computers, time or frequency determining elements of passive nature; use in digital circuitry and registers.

Housed in a sturdy metal case, with polished aluminum panel, the unit weighs approximately 3½ lbs. and measures only 4⅝" high x 2" wide x 30" long. Pickup coils are positioned along the calibrated slot and locked in place by thumb screws. Deltime Inc., Mamaroneck, New York.

Circle No. 169 on Inquiry Card



Reference Resolver

A new resolver enables accurate reference phase control during servo components and systems tests. Providing simultaneous identical phase shifts to each phase of a four-phase reference signal, the reference resolver eliminates the need for plotting two diagrams and computing the difference in plots by compensating for unknown phase shifts. Slight gain adjustment is provided in each of the instrument's input channels to accommodate variations in amplitude of input vectors. Directly calibrated 0-360° phase-shift control permits easy setting up of any desired phase shift.

When used with a transfer function analyzer, angular phase displacement is readily determined by adjustment of phase shift control to null the quadrature meter. Unit also enables synthesis of vectors for backing off other signals.

The resolver features a four-phase input of 10 volts rms per phase and a four-phase output of 10 volts or 50 volts rms per phase at any phase angle from 0-360°. Input impedance is 100,000 ohms; output impedance is less than 1 ohm per phase. Maximum output current is 7 ma rms/phase. Output phasing accuracy is ± 1 degree, assuming no error in input intelligence. Solartron, Inc., Camden, N. J.

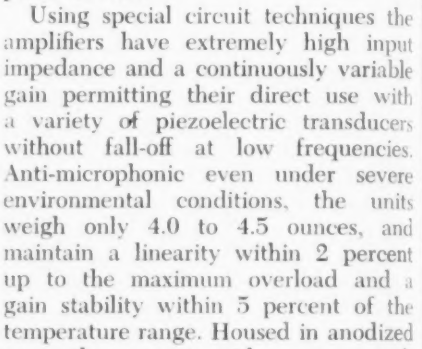
Circle No. 180 on Inquiry Card

Transistorized Amplifiers

Transistorized amplifiers, one-third the size of equivalent tube type units, need no filament power and only 20 percent of the plate power required by tube type amplifiers. The amplifiers are airborne instruments designed to amplify signals from high impedance transducers to feed directly into standard electronic meters, recorders or telemetry equipment. Operating through a temperature range of −65F to +240F., the new instruments are low microphonic voltage amplifiers, specially suitable for use in missiles, aircraft and other devices where size, weight and power consumption are prime factors.

Using special circuit techniques the amplifiers have extremely high input impedance and a continuously variable gain permitting their direct use with a variety of piezoelectric transducers without fall-off at low frequencies. Anti-microphonic even under severe environmental conditions, the units weigh only 4.0 to 4.5 ounces, and maintain a linearity within 2 percent up to the maximum overload and a gain stability within 5 percent of the temperature range. Housed in anodized cases, they operate with a recommended minimum load of 10,000 ohms, maintain a voltage gain that is continuously variable between 10 and 100 and perform with negligible vibration noise characteristics. Gulton Industries, Inc., Metuchen, N. J.

Circle No. 163 on Inquiry Card.



Silicon Rectifiers

A new line of silicon rectifiers for the home entertainment and industrial markets are rated up to 500 ma d-c output at peak inverse voltages up to 500 volts and ambient temperatures up to 100 C. They fill the needs both of original equipment manufacturers and of servicemen as they can be supplied with a variety of mounting devices.

The industrial rectifiers have ratings up to 3 amperes at 600 volts and are usable at ambient temperatures up to 150C. They are reliable components for power supply applications and for use in instruments, computers, and relays. Components Division, International Telephone and Telegraph Corporation, Clifton, New Jersey.

Circle No. 173 on Inquiry Card

Safe-load Relay

New fast-acting electrical control device stops an over-loaded electrical motor during the critical peak or starting load period. Designed to respond instantly to all momentary overloads, the safe-load relay is usable in nearly all types of motorized applications—ranging from single-motor machine tools and conveyors to multi-motored transfer and automation setups. The device can be employed in conjunction with many types of alarm systems.

A second or "limiting" pointer which can be reset very close to the actual normal electrical power required by the drive controls the action of the relay. It does not interfere with the conventional indicating pointer's movements across the dial face of the relay.

The new control relay also can be reset as instantly as it cuts off electrical current to the drive involved. A setting button allows the current-controlling pointer to be set at any current value desired.

To start a motor after a safety shut down, a small push button microswitch next to the meter face must be depressed. This releases the pointer on the meter to close the circuit for another normal start. Baker Perkins Inc., Saginaw, Mich.

Circle No. 172 on Inquiry Card

D-C Coupling Preamp

New d-c coupling preamplifier which features high performance on single-ended or balanced signals was designed for use with optical oscillographs, tape recorders, oscilloscopes and other indicating devices.

The preamplifier uses a moderate gain, balanced input-balanced output d-c amplifier, which will perform equally well with single-ended or balanced signals. A three-stage circuit has a cathode follower input and output, and its over-all gain is provided by the second stage push-pull transistor amplifier. Input is single-ended or push-pull and impedance is 5 megohms each input side to ground. A 50 mv. input produces 1 volt at output jack under maximum output load conditions. Frequency response is 0-10 kc; linearity, 1/4%. Plus or minus zero suppression, to 20 times full scale voltage, is included. Calibration is provided by a 100 mv. internal signal.

Front panel controls of the unit include sensitivity, position, attenuator, balance USE-OFF-CAL switch, zero suppression dial and IN-OUT switch, and connectors for input and output. A model without zero suppression is also available. Industrial Division, Sanborn Co., Waltham 54, Mass.

Circle No. 95 on Inquiry Card

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CIRCLE NO. 14 ON INQUIRY CARD

SERVO MOTOR APPLICATION

Transfer Function Representation of the Motor in a Block Diagram

Application of a servomotor in a system is normally the province of the systems designer. Such designers describe the motor with a block, showing voltage entering and shaft rotation emerging (Fig. 1), and represent the operation of the block mathematically.

Fig 1—Motor block diagram

If we assume 100 percent efficiency, the output torque is equivalent to the input torque

$$J\ddot{\theta}_o + F\dot{\theta}_o = K_t E$$

where θ_o = shaft angle

J = moment of inertia of the rotor

F = viscous friction constant

K_t = torque constant

E = input control voltage

Relationship between the control voltage and torque may in some cases be non-linear although in servomotors, pains are taken to linearize it. When a step input of voltage is applied to this motorblock, the shaft speed reacts thus (Fig 2):

$$\dot{\theta}_o = K_v E(1\text{-}e^{-Ft/J})$$

where K_v is the velocity constant.

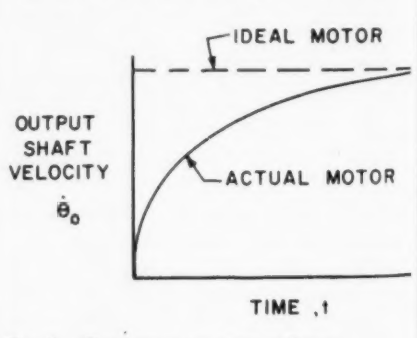


Fig 2—Response to step voltage

The action is analagous to a capacitor charging to a fixed voltage. The reciprocal coefficient above, J/F, is termed the mechanical time constant.

It is evaluated from the torque-speed relationship shown in Fig 3 as an idealized curve, linear from stall to no-load speed. Such a curve is approached in practice by careful design of rotor resistance. With a linear torque-speed curve, we have the useful relationship

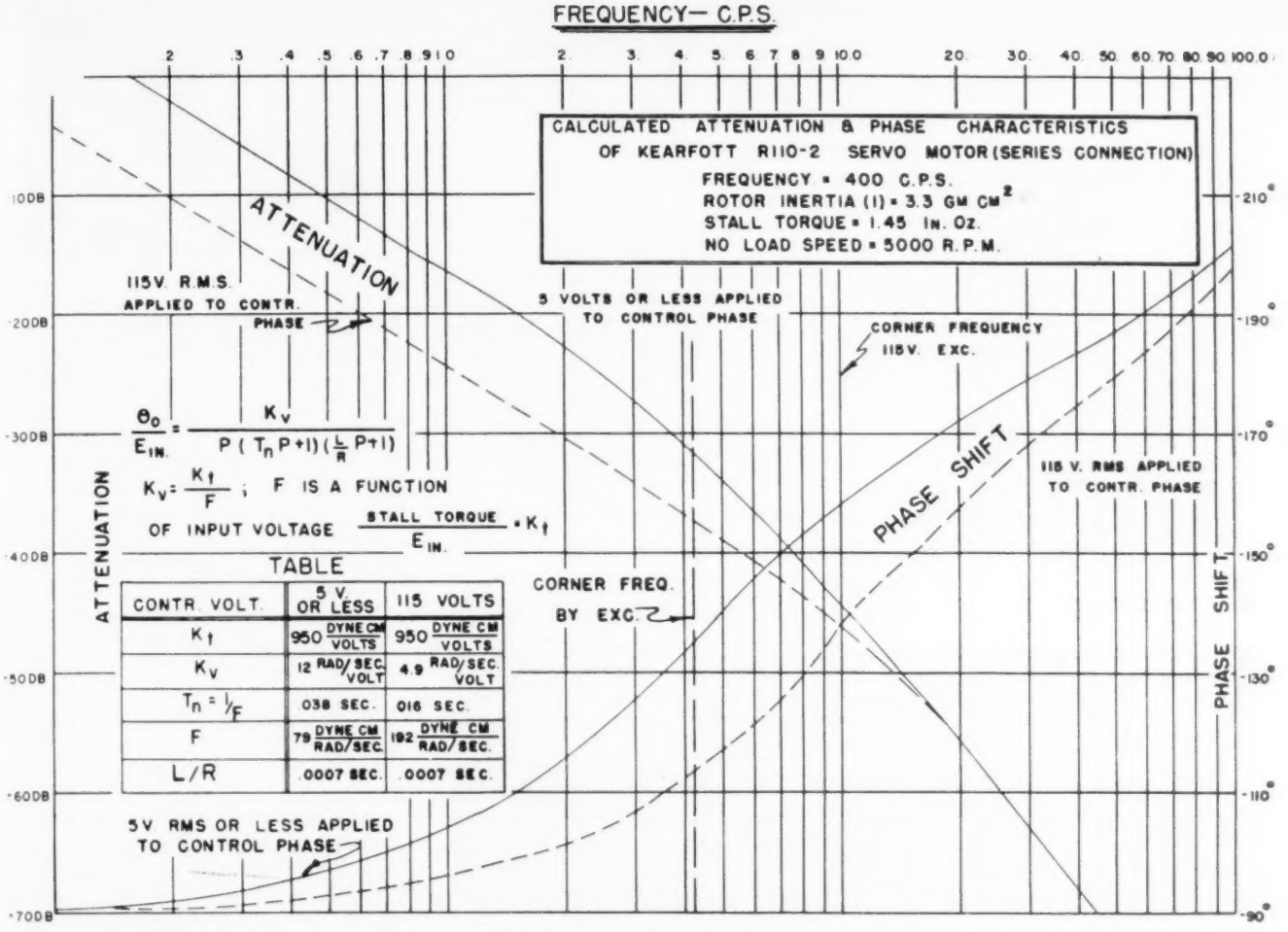

FREQUENCY— C.P.S.
CALCULATED ATTENUATION & PHASE CHARACTERISTICS
OF KEARFOTT R110-2 SERVO MOTOR (SERIES CONNECTION)
FREQUENCY = 400 C.P.S.
ROTOR INERTIA (I) = 3.3 GM CM²
STALL TORQUE = 1.45 IN. OZ.
NO LOAD SPEED = 5000 R.P.M.
ATTENUATION
115V. R.M.S. APPLIED TO CONTR. PHASE
5 VOLTS OR LESS APPLIED TO CONTROL PHASE
CORNER FREQUENCY 115V. EXC.
PHASE SHIFT
115 V. RMS APPLIED TO CONTR. PHASE
$\frac{\theta_o}{E_{IN.}} = \frac{K_v}{P(T_n P+1)(\frac{L}{R}P+1)}$
$K_v = \frac{K_t}{F}$; F IS A FUNCTION OF INPUT VOLTAGE $\frac{\text{STALL TORQUE}}{E_{IN.}} \cdot K_t$
TABLE
CONTR. VOLT. | 5 V OR LESS | 115 VOLTS
K_t | 950 DYNE CM/VOLTS | 950 DYNE CM/VOLTS
K_v | 12 RAD/SEC/VOLT | 4.9 RAD/SEC/VOLT
$T_n = 1/F$ | 038 SEC. | 016 SEC.
F | 79 DYNE CM/RAD/SEC. | 192 DYNE CM/RAD/SEC.
L/R | .0007 SEC. | .0007 SEC.
CORNER FREQ. BY EXC.
5V RMS OR LESS APPLIED TO CONTROL PHASE
ATTENUATION
PHASE SHIFT
-100B
-200B
-300B
-400B
-500B
-600B
-700B
-210°
-190°
-170°
-150°
-130°
-110°
-90°

Fig 5—Attenuation and phase shift diagram for a standard BuOrd size 15 motor (Kearfott R110 motor)

$$F = \frac{\text{stall torque}}{\text{no-load speed}}$$

The *mechanical time constant* may then be restated as:

$$t_n \frac{\text{rotor inertia x no-load speed}}{\text{stall torque}} = \frac{J}{F}$$

Thus a servo that is expected to reverse, accelerate, and decelerate rapidly should employ a motor with a low mechanical time constant. As a figure of merit, this is misleading, since it implies that small no-load speeds are desirable. More commonly accepted as a figure of merit is the maximum acceleration of the rotor from rest, or the well-known stall torque to rotor inertia ratio.

Operating on the motor equation, we may say that the transfer function of the motor block is the common one shown below.

$$KG(p) = K_v/p(t_n p + 1)$$

We would expect from this representation that the phase shift cannot exceed 180° at any frequency. Experimental data do not support this conclusion and a more complex transfer function is indicated.

$$KG(p) = \frac{K_v}{p(t_n p + 1)(cp + 1)}$$

where c is a constant for a given motor. This constant is taken as the electrical time constant, and when evaluated as the ratio L/R, yields the calculated attenuation and phase shift diagram of Fig 5 for the Kearfott R110 motor. As expected the phase shift approaches 270° in accordance with theory.

No attempt will be made to defend the use of L/R as the electrical time constant and the evaluation thereof, although the evidence bears this out. It has often been ignored since it rarely appears at lower frequencies. In this case it is theoretically estimated to have a reciprocal frequency of over 200 cps.

As shown in Fig 5, R110 performance has been evaluated both at 115V and 5V control phase excitation since these motors have increasing slope of the torque-speed curves with decreasing voltage. That is, viscous friction decreases giving a higher mechanical time constant at lower voltages.

Thus, a servo motor can be represented by a two-pole transfer function when the manufacturer linearizes the voltage-torque and torque-speed curves. A system designer then has the means to make a loop analysis and determine the degree of stability and error of the servo.

A pitfall in the block diagram approach occurs when two adjacent blocks load each other, thereby altering the characteristics that each exhibited in the isolated state. Motor input impedance is a function of operating position on the troque-speed curve as well as the fixed excitation voltage. So it must be understood that use of this method of synthesis implies an amplifier whose response is unaltered or compensated despite the fluctuation of the motor input impedance, and a motor whose characteristics are unchanged by an amplifier-loaded input. *Information for this article was obtained from Kearfott Company, Inc., Little Falls, N.J.*

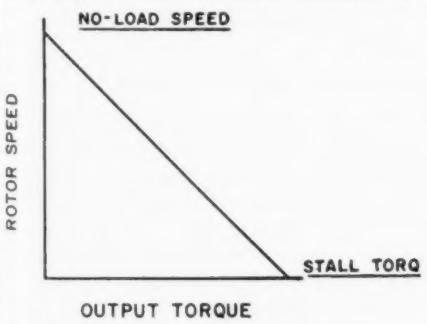


Fig 3—Torque-speed curve

Circle No. 54 on Inquiry Card

COMPONENTS

Size 5 Servo Motor

Shorter than any servo motor presently available in this diameter, a new 400 cycle servo motor in BuOrd size 5 weighs only 0.85 ounces. Requiring a starting voltage of only 0.6 volts, the motor operates at 26 volts fixed phase and 40 volts centertapped control phase with power input 2 watts per phase. Nominal no load speed is 11,000 RPM–42,000 Radians/sec^2 theoretical acceleration.

With the 40 volt centertapped control winding, it has many possible applications with transistorized amplifiers. Unique construction provides better concentricity from mounting pilot to shaft than conventional servo motors.

Stall torque is 0.1 ounce-inches minimum, maximum power output is 0.3 watts at a speed of 6,000 RPM; and operating temperature is minus 55°C to plus 85°C. Mechatrol, Division of Servomechanisms Inc., Westbury, L.I., New York.

Circle No. 177 on Inquiry Card

WORTH FILING

Small A-C Shaded Pole Motors

Catalog features extensive information on unidirectional nongeared a-c shaded pole motors. General information including charts, diagrams and data on duty cycle, power sources, variations, braking controls and explanations is accurately described. Five motor types are thoroughly discussed with such pertinent information as performance characteristics, ratings, construction, dimensions and typical applications. Reversible, synchronous, and geared motors, fan blades and enclosures are also referred to in this catalog.

Source: Barber-Colman Company
Rockford, Illinois
For your copy: Circle No. 183 on Inquiry Card

Hysteresis Synchronous Motor

Smallest hysteresis synchronous motor in BuOrd size 5 operates from a single phase power supply at 26 volts. However, units can be supplied to operate from two or three phase supplies at speeds of 12,000 or 8,000 RPM.

Operating characteristics of the unit are: Power input: 5 watts total; pull-out torque: 0.07 ounce-inches; starting time: 30 milliseconds; operating temperature range: minus 55C to plus 85C.

Unique construction provides better concentricity from mounting pilot to shaft than conventional motors. Mechatrol, Division of Servomechanisms Inc., Westbury, L. I., New York.

Circle No. 178 on Inquiry Card

Frequency Discriminator and Servo Driven Correction Loop

Transistorized frequency discriminator and servo driven correction system control a variable ratio engine transmission which drives a typical aircraft alternator at constant speed. The system is smaller, lighter and less complex than earlier systems and has an absolute accuracy of ± 0.125% (400 ± 0.5 cycles) throughout an ambient temperature range of −55°C to +125°C. Using semiconductors to reduce weight, size and complexity, the system comprises a frequency discriminator, a specialized servo amplifier, and a servo torque unit with stabilizing generator feedback for furnishing power and reference signals to the control system independently of the main aircraft alternator. John Oster Manufacturing Co., Avionic Division, Racine, Wisc.

Circle No. 70 on Inquiry Card

Tiny Servo Motor

A 1.1 ounce servo motor insures near-instantaneous response in missile and aircraft control systems. In response to signals, it can reverse directions at peak speeds in thousandths of a second and is up to eight times as fast as comparable units. A key component in electronic control networks, the motor measures 0.84 inches long and 0.75 inches in diameter. Beckman Instruments Inc., Fullerton, Cal.

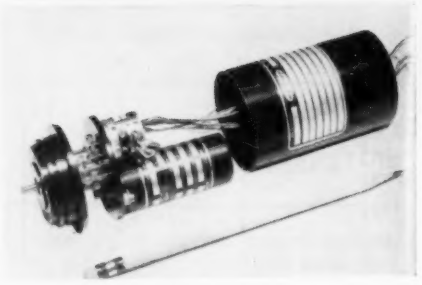
Circle No. 215 on Inquiry Card

WORTH FILING

Starting Synchronous Motors

10 page bulletin describes methods of starting various types of synchronous motors. Among the subjects discussed are full-voltage starting, part-winding starting, wye-delta starting, and field excitation.

Source: General Electric Company
Schenectady 5, New York.
For your copy: Circle No. 190 on Inquiry Card



Turret Packaging System

Precision rotating servo components can now be assembled in miniature turret packages. Unlike conventional rotating component packages which line up the components end-to-end, the turret concept requires less volume, is better suited to environmental conditions such as vibration, shock, etc., and permits greater flexibility of use of the components. For example, the motor can drive more than one component, each at the same or different gear ratios, and the output shaft allows easy connection.

A typical turret package contains a size 11 motor, a tachometer, a gearhead, and a potentiometer, all encased in a package less than 5" long, with a nominal OD of 2¼". Other servo components, such as transistorized amplifiers, synchros, etc., can be added as needed. Clutch and limit stops may be added at various stages of the gear train. Mechatrol, Division of Servomechanisms Inc., Westbury, N. Y.

Circle No. 176 on Inquiry Card

WORTH FILING

Toroidal Cores

12-page handbook for designers on the use of Genalex toroidal cores covers such things as permeability, temperature, coefficient of inductance, d-c stability, core stability, core size and finish. Complete graphs and technical data on the loss characteristics of Genalex cores are presented. The handbook charts physical and electrical properties of Genalex III cores and design notes on the use of toroidal cores are included.

Source: Wallace E. Connolly and Co.
Menlo Park, California
For your copy: Circle No. 184 on Inquiry Card

WORTH FILING

Electrical Fixtures Catalog

144-page, pocket-size catalog and wiring guide No. 21 covers complete line of surface metal raceways and fittings, Plugmold multi-outlet systems, fluorescent and slimline lighting equipment, and Wireduct non-metallic flexible conduit, with installation instructions.

Source: The Wiremold Co.
Hartford 10, Connecticut
For your copy: Circle No. 119 on Inquiry Card

A-C Bar Graph Oscilloscope

Displaying up to forty separate signals simultaneously on the cathode-ray tube, an a-c bar graph oscilloscope permits continuous visual monitoring of multichannel data from thermocouples, strain gages, piezoelectric pressure gages, flowmeters, spectrometers, electrocardiagraphs, encephalographs and many other measuring devices.

Typical uses of the instrument are: simultaneous monitoring of temperatures in many critical points in jet engines, checking and monitoring the output of each channel in a multichannel telemetering system, measurement of the distribution of strains along an aircraft wing during dynamic testing, monitoring pressure via piezoelectric gages in turbo systems, monitoring flow rates in chemical processing, and determination or monitoring of temperature distribution in petroleum cracking units, along distillation columns and in annealing ovens.

The scope presents its display as a vertical bar graph 9 inches high by 12 inches wide on a 17-inch cylindrical-face cathode-ray tube. The height of each line is a linear function of the input signal level and the lines are terminated with a dot at the top and at zero for increased reading accuracy. A transparent cathode-ray tube overlay provides 40 vertical identification lines and 100 evenly spaced horizontal lines with every tenth line double width. Switch for each channel permits any one of the 40 signals from the display to be connected to an auxiliary oscilloscope for waveform analysis.

With a scanning rate of 400 channels per second and a 10-per-second frame rate, the instrument's sensitivity for each channel is 10 millivolts for 9-inch vertical deflection. Frequency response is ±2.0% from 10 cps to 10 kc and down no more than 3 db at 50 kc. Input impedance is 200 kilohms shunted by approximately 150 mfd. Industrial Products Division, International Telephone and Telegraph Corporation, Lodi, N.J.

Circle No. 88 on Inquiry Card

WORTH FILING

Laboratory Centrifuges

12-page catalog describes 1958 laboratory centrifuges with keyboard control center. 7 models are available: Size 1; Size 2; Size 2 Refrigerated Hematocrit; 15 ml, 6 tube constant speed Centrifuge; 15 ml, 6 tube variable speed to 5000 RPM Centrifuge; and Clinical model with angle and swinging heads.

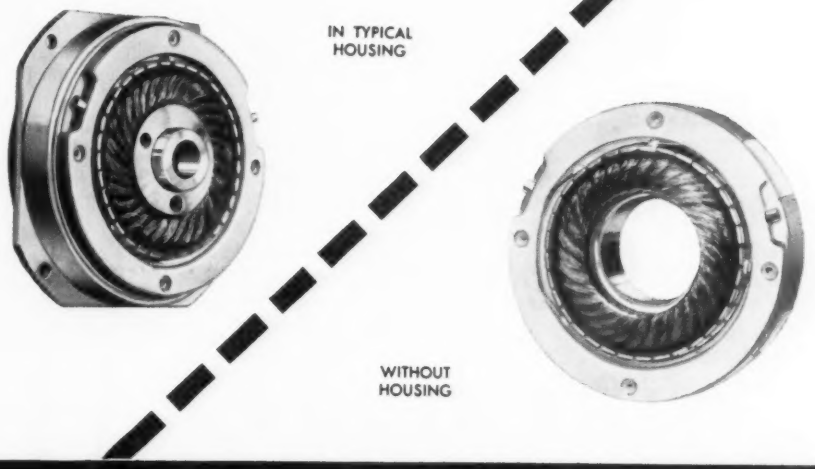
Source: Chicago Surgical and Electrical Co.
Chicago 22, Illinois

For your copy: Circle No. 118 on Inquiry Card

a Complete line of

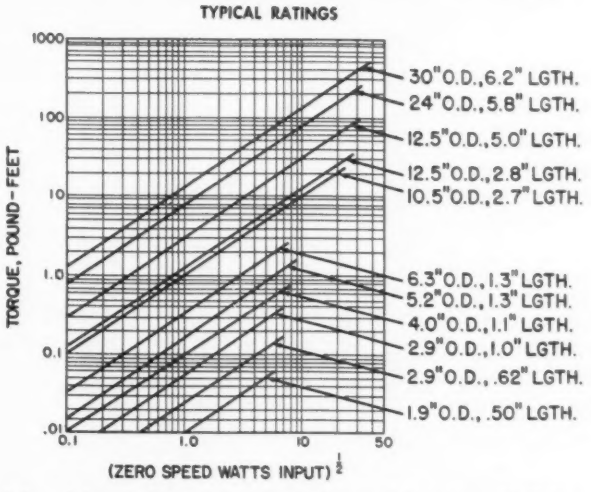
D. C. TORQUE MOTORS

FOR DIRECT DRIVE SERVO APPLICATIONS



- High angular acceleration by utilizing direct drive (4,000 rad./sec.^{2})
- High peak torque per unit volume
- Minimum control and total power input
- Rapid electrical response
- Optimum shape for compact systems

THIS DESIGN TAKES MAXIMUM ADVANTAGE OF THE PROPERTIES OF DC CONTROL POWER AND PERMANENT MAGNET FIELDS.



Matching Rotary Amplifiers Also Available

For further information and Catalog write to:

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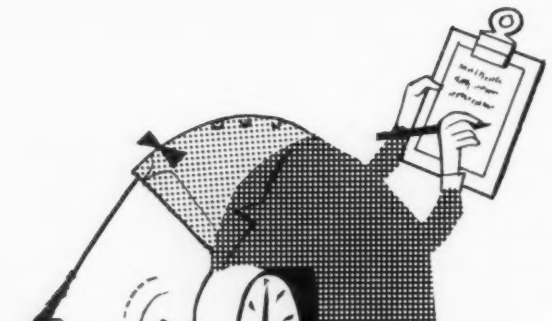
CIRCLE NO. 16 ON INQUIRY CARD

MANAGEMENT

Engineering Executives— TIME STUDY YOURSELF



Oliver G. Haywood, Jr.
Contributing Editor

ALL executives bemoan the lack of time to do all they want to do. Few apply to themselves management techniques they consider standard for the control of others.

Effective control of any operation requires that each supervisor tell each subordinate, or provide a system that tells him:

- What he is expected to do
- What he is doing
- His authority to change what he is doing

The second element, "What he is doing", sounds trivial. Surely everyone knows what he is doing. Unfortunately, most accounting reports are designed for top management and fail to provide lower level supervisors with data they need for proper understanding and control of their operations. Similarly accounting reports do not tell supervisors how they are spending their own working hours, an essential step toward changing established working habits to provide better use of time. This column presents a simple time-and-motion-study approach for any supervisor who desires to find out where his time actually goes.

To jot down at the end of the day how the day was spent leads to under-allocation of time to the little five-and-ten-minute discussions and interruptions and over-allocation to important matters that remain uppermost in the mind at the end of the day. Clocking in and out on each item of work is obviously impractical. The problem is to obtain a simple procedure that gives an unbiased approximation—unbiased either toward or away from what the executive thinks he should be doing.

I used a recording of just what I was doing at four randomly-selected times each day, for a period of forty consecutive working days. The method has error, of course —in effect, it gives a two hour weighting to whatever I was doing at the randomly-selected instant of observation. On the other hand, each observation represents less than one percent of the survey. The method is certainly unbiased.

To obtain random times, I once taught a secretary how to use a table of random numbers. She selected times from a book of 10-digit random numbers, using only the last four digits. Be sure to insist on four digits; ie, 9:45 can not be any number ending in 945 but only one ending in 0945. Otherwise, times will be non-random with a bias of 10 to 1 against times from 10:00 to 12:59, as well as some distortion of times from 1:00 to 2:59.

For a random device on another occasion, I used a deck of playing cards with the sevens, eights and kings removed. The number of the card set the hour, the suit, the minute by quarter-hours. The ten of clubs was 10:00; the ace of diamonds 1:15; the four of hearts 4:30; and the queen of spades 12:45. This system does not give truly random numbers, and would be completely unacceptable if particular events tended to happen at the quarter-hours. Such is rarely the case in executive operations. I concluded that for my work this method of selecting times gave a set of unbiased observations.

I have conducted two surveys on myself. At the time of the first survey I was engaged in organizing an engineering laboratory for a missile systems study—an entirely new field for the company. The organization had 50 people, about two-thirds of whom were professional engineers. At the time of the second survey, I was general manager of a 2200-man semi-autonomous division handling its own engineering, manufacturing, sales, contract negotiations, etc. Each survey was handled largely by my secretary who checked with me if she could not tell what I was doing.

Prior to the surveys, I divided my activities into three general categories: the nature of my individual action, the nature of the matter being acted upon, and the type of management function I was performing. Each general category was subdivided into a number of separate items. At each selected time of observation, one item was checked under each of the three general categories of management activity. Results of the survey were of principal interest to me, but are tabulated below as perhaps of some interest to other engineering executives.

	Laboratory Manager (1954)	*Division Manager (1957)*
NATURE OF INDIVIDUAL ACTION		
Conference with one person (including telephoning)	*20%*	*16%*
Conference with two or more persons	*34*	*27*
Writing or dictating	*26*	*14*
Editing or approving work of others	*0*	*1*
Reading	*3*	*2*
Out-of-office inspection of operations	*0*	*5*
Out-of-town travel	*17*	*35*
NATURE OF MATTER BEING ACTED UPON		
Engineering	*33%*	*39%*
Manufacturing	..	*24*
General administration	*53*	*25*
Community and scientific goodwill	*13*	*12*
Own professional development	*1*	*0*
NATURE OF MANAGEMENT FUNCTION BEING PERFORMED		
Planning	*33%*	*35%*
Appraisal and assignment of individuals	*18*	*7*
Analysis and control of operations	*36*	*28*
Selling (including review of bids as well as customer contacts)	*13*	*27*
Formal training programs	*0*	*3*

To an operating manager, information is of value only as a basis for action. A survey such as proposed above satisfies only idle curiosity unless the executive analyzes the results to see whether he is doing what he thinks he should be doing, and does something about it if he is not. This is decidedly a matter to be determined by the executive himself with due consideration to both his techniques of management and the nature of operations he is managing. Since I have detailed results of my own surveys, it may be of interest to some readers for me to cite a few actions I took. All are based on the first survey.

Noting that 40 percent of my time in the office was spent in conferences with two or more people, I organized my office as a conference room, with blackboard, conference table, and sufficient chairs. This arrangement saved office space, saved my time in going to conference rooms, and permitted scheduling of conferences at any time. It also served the useful purpose of deemphasizing my desk, too often a symbol of authority and a roadblock to easy communication with subordinates. Incidentally, the large percentage of time spent in meetings to generate programs and to assure understanding of organization plans and policies probably accounts for the small amount of time spent in actual approval of work of others.

To reduce time I spent on general administrative matters, I organized a Business Group to handle contract administration, purchasing, publications, communication and travel services, cost accounting, security, and similar administrative functions. This concept of a Business Manager and a Business Group to support the technical operations proved sufficiently successful to be adopted by three other organizations of the Company. Before the second survey, I had changed companies and organized a division, establishing a similar business group. It is interesting to note that I was devoting half as much of my time to general administration at the time of the second survey although I was managing an organization 44 times larger.

The time spent on formal training of supervisors was clearly inadequate. We started a training program, including both technical orientation-type biweekly lectures and a series of general management conferences conducted by both guest speakers and company officials.

The surveys cover only normal office hours. The low percentages for reading, editing work of others, and own professional development reflect the fact that most executives have to devote many evenings and traveling hours to keep up with reading matter of their profession and office.

Executives who try this survey may find some shortcuts to permit better use of their time. They will probably find they should and can allocate more time to their more important responsibilities. Unfortunately, they will certainly find no open sesame to ample time. Executives as a group work long hours. Engineering executives must add to these hours the time they devote to maintaining some competence in their professional field. But an essential step toward increased effectiveness for anyone, including an executive, is to know what he is actually doing. END

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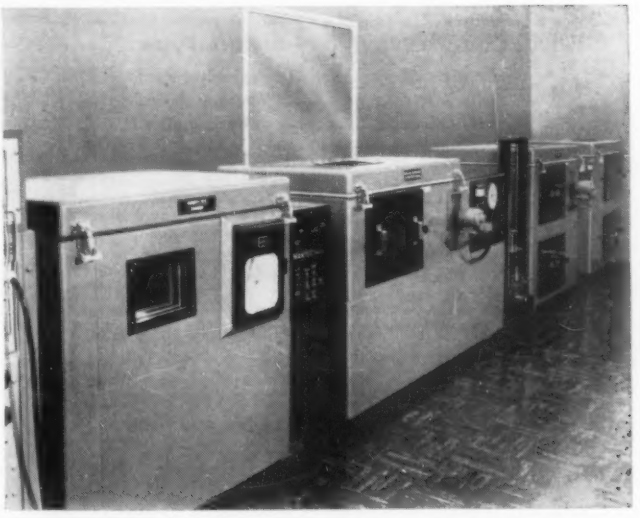

chambers. Other types of environments obtainable in Mantac PET packages include temperature shock, salt spray, fungus, sunshine, rain, sand-and-dust, immersion, accelerated corrosion, radiant heat, and explosion. Mantac Inc., El Segundo, Calif.

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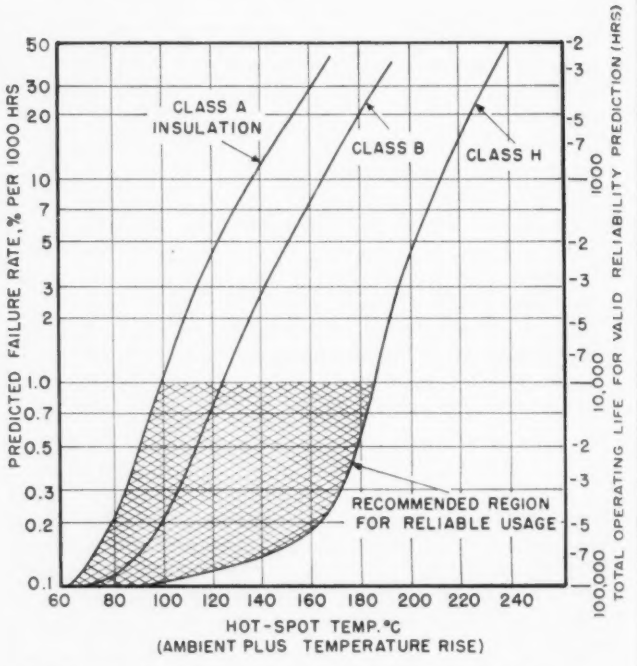
DESIGN TIME SAVER

Reliability Stress Analysis For Rotary Electrical Devices



Predicted failure rates for transformers, chokes and coils.

This description of stress analysis procedure applies to such devices as motors, blowers, generators, dynamotors, synchros, and resolvers.

These devices can be thought of as having two major areas of failures: electrical and mechanical. Since the winding consists of insulated wire on a magnetic core, it is quite analagous to a transformer and can be rated in the same manner as far as electrical failure hazard is concerned. Mechanical failures are generally associated with bearings and brushes, and are considered to be due to frictional effects. Consequently, since frictional phenomena are a function of speed, the estimated mechanical failure rate must consider speed of rotation.

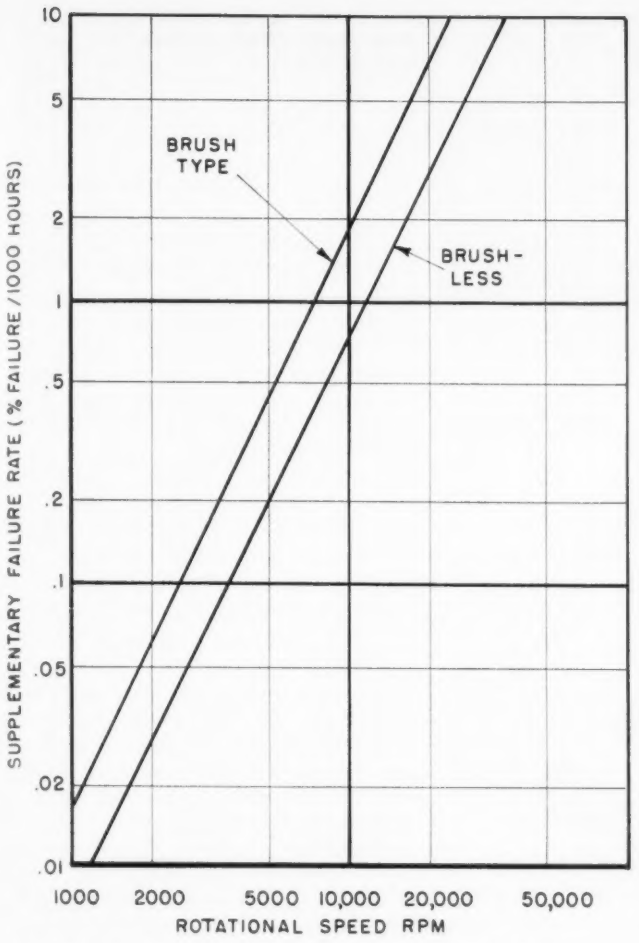
In accordance with the philosophy outlined above, the following steps are to be taken in estimating the failure rate for a rotary electrical device:

Step 1: Determine from the specification the permissible temperature rise, and the class of insulation.

Step 2: Refer to the Transformer Curve Fig 1. Using the results of Step 1 and an estimate of the operating temperature, determine the estimated electrical failure rate.

Step 3: Refer to the Motor Curve Fig. 2 and determine the failure rate associated with mechanical wear. Note that two curves are given: one applying to devices having commutating brushes, and one for devices without brushes. Slow-speed devices like synchros and resolvers have rotational speeds so low as to result in negligible (less than 0.01% per 1000 hours) values of this supplementary failure rate.

Step 4: Add the failure rates from Steps 2 and 3 to find the net total failure rate.



Predicted failure rates for rotary electrical devices as a result of mechanical wear.

Example: Consider a 4000 RPM brush-type direct-current motor, which according to the specifications uses class-B insulation. Furthermore, it is estimated from the known environment and the specifications that a hot-spot temperature of 110°C is to be expected.

First, refer to the transformer curve, Fig. 1, to determine the electrical failure rate. On the basis of class-B insulation and a 110°C hot-spot temperature, a failure rate of 0.33%/1000 hours is indicated.

Then, refer to the motor curve, Fig. 2, and note the mechanical failure rate corresponding to a 4000 rpm brush-type motor. This is observed to be about 0.30%/1000 hours.

Finally, add the results of the previous steps to obtain a total estimated failure rate of 0.63%/1000 hours.

These reliability procedures and failure rate curves are taken from "Reliability Stress Analysis for Electronic Equipment–TR1100," prepared by the Engineering Standards and Services Section of Defense Electronics Products, Radio Corporation of America, for internal use. With permission from RCA the Department of the Navy has made the handbook available as PB-131678 from Office of Technical Services, U.S. Department of Commerce, Wash. 25, D.C.–Price $3.00. The handbook presents in one convenient source, the basic techniques and numerical values required to calculate the reliability risks in the process of making electronic design commitments.

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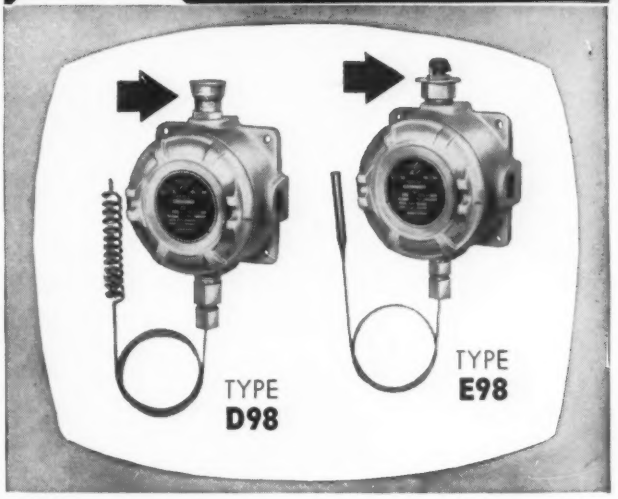

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STAFF COLUMNIST

David Bandel
Associate Technical Director,
TRACERLAB, INC.

PROGRESS IN PRINTED CIRCUITRY: Part 2

Studies of Etchants for Copper

This is the second part of the summary on a symposium held during the Spring Meeting of the American Chemical Society in San Francisco.

IRON SALTS

A rapid, simple and accurate method of evaluating the effect on etching rate of such variables as concentration of etching species, concentration of additives, temperature and concentration of dissolved copper was reported by L. H. Sharpe, of Bell Telephone Laboratories. Data on the behavior of ferric nitrate, ferric sulphate and ferric chloride as etchants for copper were presented. These studies were conducted by plating out copper on a platinum cylinder, by the rotating cathode procedure and exposing the plated copper to the etchant under study. Etching time was determined by following the potential of the electrodeposited copper with respect to a platinum reference electrode in the etching solution. As the copper is etched, the potential will remain steady or decrease slowly until some underlying platinum is exposed. At this point the potential will undergo a sudden decrease and will continue to decrease until all the copper is etched away. The time at which the potential is decreased to one-half the initial value is taken as time required to strip the copper deposit. This measurement turns out to be reproducible to within a few percent.

Etching rates were studied by this procedure on copper thicknesses of 0.9 mil deposited on the platinum cathodes. The concentration of ferric sulfate, nitrate and chloride was varied to determine the concentration of the ferric salt solution for maximum etching rate in each case. Temperatures of 25°C and 35°C were used in the case of the chloride. The results of this series is summarized in the table below.

Ferric Salt Etchant	Temperature °C	Conc. of Salt at Maximum Etching Rate Molarity	Time to Etch .0009″ Copper at Optimum Salt Conc. Minutes
Nitrate	35	1.75	2.5
Sulfate in Water	35	0.65	8.8
Sulfate in 4N H_2SO_4	35	0.8	9.0
Chloride	25 35	2.25 2.25	2.1 1.9

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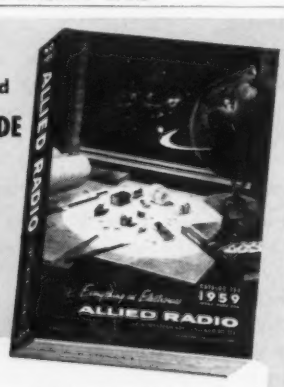

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Ferric chloride is obviously the most effective etchant of this series. All etchant salts pass through a minimum in an etching rate vs. concentration plot. This is due to the interaction of three concentration dependent factors which influence etching time: (1) increase in etching salt concentration increases oxidizing agent concentration and decreases etching time, (2) increase in etching salt concentration increases viscosity, tending to increase the etching time, and (3) the activity coefficient of the etching ion species decreases as concentration is increased, tending to lessen the ability of further additions of etching salt to decrease etching time. At concentrations below the optimum rate, factor (1) is predominant and factors (2) and (3) become controlling as the etching salt concentration increases.

The etching rate decreases rapidly as copper ion builds up in the etching bath. The magnitude of this effect was investigated by adding copper to the ferric chloride etching bath. At 2.25 molar concentration, the optimum concentration determined experimentally, etching time rises rapidly as the copper concentration increases. It rises less rapidly for the 3.75 molar solution normally supplied to the printed wiring industry. The results show, however, that the 2.25 molar solution has definite advantages over the 3.75 molar solution normally used. The 2.25 molar solution provides shorter etching times up to the point of 70 grams of copper per liter of solution. Since the conventional ferric chloride etchant is discarded when the copper reaches 60 grams per liter there is a time and cost advantage in using the 2.25 molar ferric chloride etching bath.

COPPER SALT ETCHING BATHS

The evaluation of copper chloride solutions as etchants was discussed in a paper by L. H. Sharpe and P. D. Garn of Bell Telephone Laboratories. The techniques used to measure etching rates was the same one described above for ferric salts. Simple aqueous solutions of cupric chloride are much too slow in action. Addition of hydrochloric acid increases the rate of etch considerably. Other sources of chloride ions are also highly effective in increasing the etching rate of cupric chloride. Solutions of cupric chloride saturated with ammonium chloride had higher etching capacity than 6N hydrochloric acid or saturated sodium chloride as well as a higher overall etching rate. The saturated ammonium chloride–cupric chloride etching bath–also maintains a fairly constant rate of etch over a wide range of added copper, which is highly desirable from the standpoint of process control.

Even though a large increase in added copper tolerance has been achieved for cupric chloride etchant by ammonium chloride addition, this etchant still does not compare too favorably with the ferric chloride etchant with respect to the rate of increase of etching time with added copper. If the cupric chloride etchant bath could be regenerated continuously as it was being used, it would merit serious consideration as a production process for printed wiring, since no feasible process for regenerating ferric chloride etchant baths has been devised. By choosing the proper electrode conditions and plating potentials, it is possible to regenerate the cupric chloride baths efficiently and recover salable metallic copper as a by-product. Electrolytic regeneration of cupric chloride etchant also permits automatic control of the process and the cupric chloride bath becomes an infinitely reusable etchant which is under control at all times and eliminates the disposal problem of spent solutions. Comparative etching carried out on test panels, using ferric chloride and cupric chloride as etchant in a miniature splash etcher and air agitated tank, showed that cupric chloride is more rapid than ferric chloride and produces an etch at least as clean as ferric chloride with somewhat less undercutting.

ELECTROLYTIC REGENERATION OF COPPER CHLORIDE ETCHING SOLUTIONS

The final paper in this study of etching solutions was presented by P. D. Garn and L. H. Sharpe of Bell Telephone Laboratories. A process for continuous regeneration of cupric chloride etching baths was described. The chemical action of one mole of cupric ion on copper metal results in 2 moles of cuprous ion. In order to regenerate such a bath, it would be necessary to reduce cuprous ion to metallic copper at one electrode and oxidize cuprous ion to cupric ion at the other electrode. Under normal procedures, this is not possible, since cupric ion in concentrated chloride solution is reduced to cuprous ion more readily than cuprous ion is reduced to copper. However, by using a polarizable cathode and a comparatively non-polarizable anode, the reduction and oxidation reactions can be made to go in the proper directions. This is accomplished by controlling the current densities at the appropriate electrodes. The net effect of the electrolytic regeneration process is to oxidize part of the cuprous ion to cupric ion and reduce an equal part of the cuprous ion to copper. This is the reverse of the etching process.

On a laboratory device this principle of electrolytic regeneration was tested using a 2 molar cupric chloride solution saturated with sodium chloride and 20 grams per liter added copper. The solution was regenerated electrolytically more than 30 times without any apparent change in solution characteristics. The copper was allowed to re-dissolve and the solution was regenerated repeatedly. Potential measurement during the etching process showed that the etching solution behaved the same throughout the entire experiment. In a production apparatus, the metallic copper must be removed continuously. This can be done in several ways which recover the copper in a salable massive copper form.

The regeneration process is readily amenable to automatic control by comparatively simple procedures. Several were suggested by the authors. Economic data on the operation of such a unit was also given. The cost of electric power to regenerate the solution used to etch 200 square feet of 2 oz. copper is about $0.20. The cost of an equivalent ferric chloride etching bath is about $70. The copper recovered by electrolytic regeneration has a market value of $5. Automatic control and improved quality are additional plus factors for the electrolytic regeneration process.

Miniature Toroidal Signal Transformer

Transformers which employ toroidal design have the advantages of nearly perfect coupling between primary and secondary and cancellation of pickup caused by stray fields. A new toroidal signal transformer can be used in low-level applications where high impedance, low phase shift, and minimum pickup are required. Able to make use of input voltages as low as one-half microvolt, the units are used for transformation of signals. . . . for modulator circuits of the chopper and diode ring type, in the summation or ratio division of signals, and in transistor, vacuum tube, and interstage coupling circuits. Manufacturer will supply any ratio within the range of 1:1 to 1:1000 as standard in a case measuring only 1 inch in diameter and less than one-half inch thick. With a weight of 0.5 ounce, and temperature range −55° to +100°C, the units can withstand extreme shock, and are fully encapsulated and hermetically sealed to meet MIL-E-5272A and MIL-T-27A specifications. The line was designed for use with printed circuit boards or for stacking on a single screw for chassis mounting. Arnold Magnetics Corp., Los Angeles, Calif.

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COMPONENTS

Strain Gage Bridge Balance Box

Miniature strain gage bridge balance box provides means for interconnecting a power supply and 18 strain gage bridges to a multi-channel recording instrument. In addition, the unit can balance bridges, establish the desired sensitivity and remotely calibrate each channel automatically. Miniature multi-turn potentiometers provide for electrical balance and a plug board accommodates selected fixed sensitivity resistors which are easily changed to desired values. A rotary solenoid operates a stepping switch for automatic calibration of each channel.

All input and output connections are through miniature quick disconnect plugs which have safety latches. The instrument measures 7-1/4″ x 4″ x 3-1/2″, weighs less than 2-1/2 pounds, and since 18 input plugs are provided, is extremely versatile. Datran Electronics, Manhattan Beach, Calif.

Circle No. 90 on Inquiry Card

WORTH FILING

Lead Sulfide Detectors

A state-of-the-art report on the properties of Infratron lead sulfide detectors is now available to readers concerned with the design of optimum performance infrared systems or controls. This 8-page report provides a complete description, carefully illustrated and documented, of performance characteristics of a wide range of lead sulfide detectors. The study further shows how Infratron detectors can be produced in unlimited quantities with long wavelength response and with close control of such important parameters as resistance, time constant, responsivity, S/N and NEP with a degree of stability not previously available under a broad range of environmental conditions.

Source: Infrared Industries, Inc.
Needham Heights 94, Mass.
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WORTH FILING

Miniature Industrial Clutch & Brake Data

4-page leaflet describes the performance, specifications and dimensional characteristics of the new Autotronics Industrial Miniature line which features high torque rating, rapid response, zero backlash and light weight.

Source: Autotronics, Inc.
Florissant, Missouri
For your copy: Circle No. 110 on Inquiry Card

WORTH FILING

Marman Clamps, Couplings, and Joints

Attractive file folder of two-color brochures illustrated with photographs and dimensional diagrams describes clamps, couplings, and joints for industrial uses and provides detailed information on applications, sizes, and dimensions. Installation instructions are also included.

Source: Marman Division Aeroquip Corp.
Los Angeles 64, Calif.
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2 and 3-Dimensional Cams

12-page brochure gives the most complete story to date on 2D and 3D Cams, covering design and functions of 2 and 3-Dimensional Cams, their uses and formulas. Discussed are such questions as "What is a Three Dimensional Cam?" . . . "Why use a Three Dimensional Cam?" . . . "Three Dimensional Cam Applications" . . . "Mechanics and Engineering of the Three Dimensional Cam". Illustrated are many of the special 3D Cams Parker has made for leading companies for conventional and unusual control applications.

Source: Parker-Hartford Corporation
Hartford, Conn.
For your copy: Circle No. 106 on Inquiry Card.

Precision Gear Box

New gear box provides a choice of gear reductions from 1:1 to 3125:1. Unit may be assembled in an almost unlimited number of gearing configurations from stocked shafts, gears, antibacklash gears, and slip clutches. Standard shafts provide extensions on both sides and at any of the intermediate gear passes.

This predesigned gear box eliminates the time, cost, and engineering effort required to develop special gear trains. Constructed of anodized aluminum alloy and stainless steel, its diameter is 2.875 inches and length is 1.090 inches. Gears are AGMA Precision 1 or better, ball bearings are ABEC 7 double shielded. Zero backlash is available in all ratios. Precision Mechanisms Corp., East Meadow, New York.

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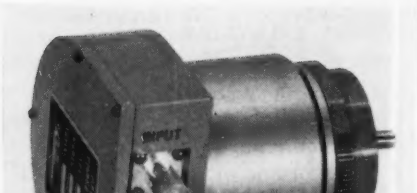

Phase Shifter

A high accuracy phase shifter designed especially for precision radar applications operates on the standard frequency of 81.95 kc—equivalent to 2000 yards—and maintains accuracies of better than ±20 minutes over an ambient temperature range of O°C to 50°C. This high accuracy is made possible by incorporation of a heater winding and thermostat within the unit. A nylon jacket over the case enables the thermostat temperature setting of 60°C to be reached within a 15 minutes warm-up time from room temperature of 25° C. Phase shifter operates without the use of slip rings assuring long life and noise-free operation. An output phase shift of 720° is provided for each 360° of input shaft rotation. Reeves Instrument Corp., Garden City, N. Y.

Circle No. 71 on Inquiry Card

Reduction Mechanism

A series of motors utilizing a gear-box, clutch and re-set mechanism capable of a 7 million to 1 reduction provides a shaft rotation as slow as one revolution in 32 hours. The clutch will drive a load of 45 oz-in and the return spring will exert up to 65 oz-in of torque. Re-set mechanism re-sets the shaft to a zero position when the motor power is interrupted. Designed to withstand the environmental requirements of the military specification MIL-M-8609 with an expected life of 5000 hours, the primary application at present is in flight training programmers. Dalmotor Division, Yuba Consolidated Ind. Inc., San Francisco, Calif.

Circle No. 171 on Inquiry Card

Recording Volt-Ammeter and Inkless Recorder

16-page bulletin describes with text, pictures and tables; applications, features, accessories, ratings and prices of portable and switchboard models of a hook-on recording volt-ammeter and an inkless recorder.

Source: General Electric Company
Schenectady 5, New York
For your copy: Circle No. 187 on Inquiry Card

Pressure Feedback Valve

New dynamic pressure feedback (DPF) valve facilitates the damping of high inertia resonant loads in hydraulic servomechanisms. The valve is a simple, reliable approach to the problem of closed loop dynamic performance in intertia-loaded servo systems while maintaining high static stiffness. Cylinder differential pressure is fed back internally through a frequency-sensitive hydraulic network, providing controlled dynamic pressure-flow characteristics which introduce effective damping. Sensitivity of flow to load pressure can be tailored to provide optimum damping for a particular load.

Although this technique is similar in effect to that achieved by use of a piston bypass orifice with a standard flow control valve, the characteristics of DPF are more linear and the power dissipation associated with bypass orifices is eliminated. Furthermore, with DPF, modified pressure-flow characteristics are obtained *only* in the frequency region where they are required for improved stability. At low frequencies, the DPF valve functions as a flow control value to provide characteristically high system stiffness. Wide variations in gain and effective time constant of the pressure feedback are possible, enabling design of individual valves to meet specific system requirements. Moog Valve Co. Inc., East Aurora, N. Y.

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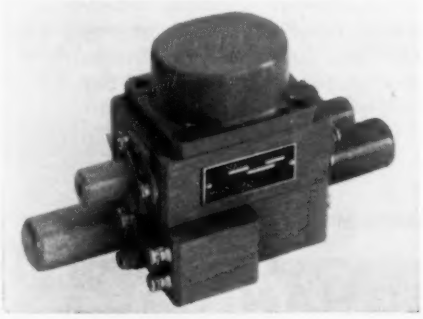


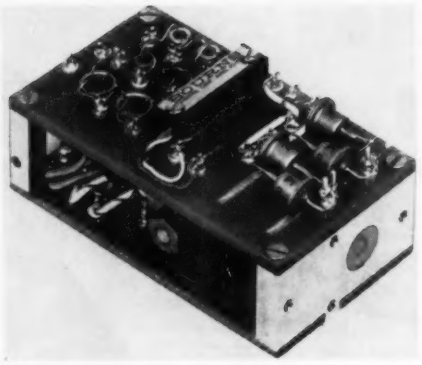
WORTH FILING

Flow Regulators

16-page catalog of pressure-compensated flow regulators for hydraulic power systems includes full-range adjustable, limited-range adjustable, and factory-set fixed-flow models. Sectional illustrations and dimension drawings are given for all models, together with enough information to enable the designer to make his own regulator selection in most cases. Also included is an orifice-flow chart and a page of helpful engineering data.

Source: Waterman Engineering Company
Evanston, Illinois

For your copy: Circle No. 182 on Inquiry Card



Silicon DC Power Supplies

Two a-c to d-c power supplies that employ silicon semi-conductors and high-temp components will withstand a 100G, 6 millisecond shock; 15G vibration, 0-200 cps; and 100G acceleration. Regulation is better than 0.1%—no load to full load—stabilization is better than ±0.02% for input voltage changes of ±10%, and ripple voltage is less than 0.2% for typical 150 volt output at 0.5 amps. Both models feature miniaturized packaging, short circuit protection and high gain regulation. One model has a current rating of 0 — 1.5 amps, and the other is rated at 0 — 0.15 amps. Both are factory preset to any specified output voltage between 100 and 200 volts, adjustable by potentiometer to ±5%. Power Sources Inc., Burlington, Mass.

Circle No. 196 on Inquiry Card

WORTH FILING

A-C Drives

16-page, full-color booklet describes in brief copy and illustrates with full-color photographs and diagrams Reliance drives, which provide precise, adjustable machine speeds from in-plant a-c circuits. The manufacture and functions of the drive components, including regulators, exciters, motor-generator sets, operator's panels and Super T motors are graphically covered. Also listed are condensed drive specifications, dimensions, accessories and applications.

Source: Reliance Electric and Engineering Co.
Cleveland, Ohio

For your copy: Circle No. 181 on Inquiry Card

WORTH FILING

Solder Terminal Wall Chart

21″x27″ wall chart shows actual scale drawings, including dimensions and materials, of 60 of the most commonly used Cambion solder terminals for design engineers constantly working with circuit design problems. It also describes in detail the Cambion solder terminal kit for design engineers.

Source: Cambridge Thermionic Corp.
Cambridge 38, Mass.

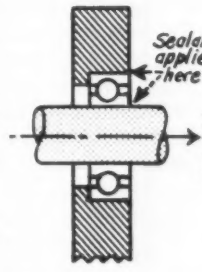
For your copy: Circle No. 122 on Inquiry Card

Edwin F. Oblinger, Chief Engineer, Parker Sweeper Company, says:

"WE THREW OUT PRESS FITS FOR BEARINGS..."

"We used interference fits to prevent bearing races from turning in the gear box of our 4HP Turbosweeper. Maintaining close tolerances was a constant headache. If the fit was loose, the race would slip and fret the surfaces; if the fit was tight, the race would deform and bearing life would be shortened. Then we discovered LOCTITE Liquid Sealant would do away with the need for press fits. We opened up the tolerances for both shaft and housing and used a slip fit, filling the clearance with LOCTITE. The bearings are retained with a force equal to the customary interference fit, but we've reduced rejected parts from 8% to less than 1% and reworked parts fell from 20% to 0! Field reports are excellent."

LIQUID SEALANT . . . replaced interference fits and opened up tolerances almost 0.002 in. on shaft and housing for this ball bearing assembly. Load of over 1000 lbs. is needed to break bond.



LOCTITE is a penetrating liquid that hardens only after being confined between closely fitted metal parts. In the absence of air, the sealant hardens into a strong, heat and oil-resistant bond. The hardening action may be accelerated by heating.

LOCTITE eliminates the need for interference fits on bearings, sleeves, shafts and studs . . . locks nuts to bolts, seals pipe and tubing joints. For further information write to:

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AMERICAN SEALANTS COMPANY
109 Woodbine St., Hartford 6, Conn.
In Canada: J. S. Parkes & Co., Ltd., Montreal

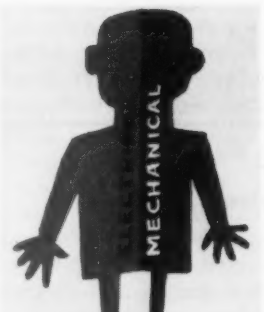
CIRCLE NO. 25 ON INQUIRY CARD

what ↓ who

is an electromechanical design engineer?

For years industry teamed the electronic engineer with the mechanical engineer so that they could design together what each could not develop alone. This merger—still current practice—has brought forth a new breed of engineer: the designer who combines the ideas and techniques from both fields into new and improved products for industry, the military and the consumer.

He's the engineer with one foot planted



firmly in electronic theory and practice and the other in mechanical theory and practice. He selects and specifies electronic and mechanical component, materials and sub-systems for application in today's and tomorrow's market—the *electromechanical* Original Equipment Market.* Proof? Just look at any of the machinery, equipment, appliances and military systems now rolling off our production lines.

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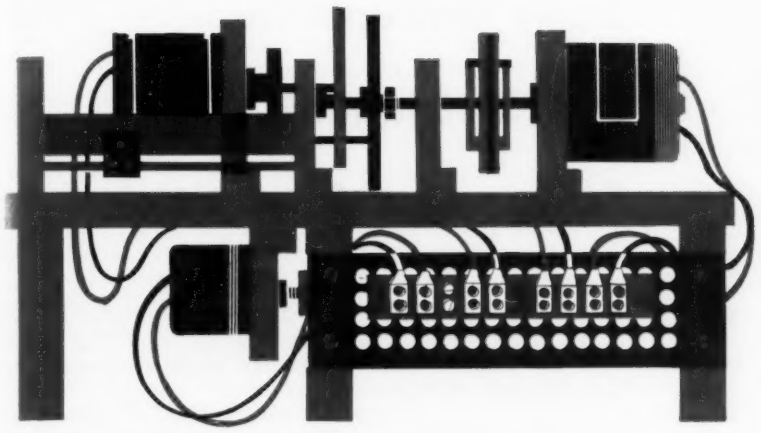
COMPONENTS DIGEST I



A-C Instrument Servomotors

Components Digest is a new kind of technical reporting that presents key facts on commercially available components in compact usable form for electromechanical engineers. It will contain electrical and mechanical theory, design data, and selection factors for families of components and will include pertinent standards, bibliographical references and buyers' guide information.

Data on performance characteristics of commercially available components will be supplemented with indications of current off-the-board redesigns and new designs that will be commercially available in the near future—wherever manufacturers will release information. Our editors will attempt to obtain internal company reports and other sources of unpublished data to amplify the normally available material. We will maintain a critical engineering viewpoint in the analysis and calculation of all data.

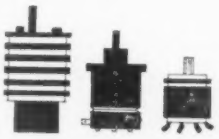
Each Components Digest supplement will cover either one or several topics, depending upon its scope. Topics will always appear on separate sheets to permit the reader to organize these sheets in a filing device.

As new data accumulate on topics previously covered our editors will issue up-to-date additions to maintain the usefulness of the previously published material, so that as time goes on a complete and continuously up-to-date file on each class of components will exist.

As a result our readers will often be able to make their initial component selections from a single reference, subject to confirmation by direct contact with several manufacturers tentatively selected from the Components Digest.

Future issues of Components Digest will cover the following topics, not necessarily in the order given: servo amplifiers, sensitive relays, integrating tachometers, precision potentiometers, analog-to-digital converters, fans and blowers, variable speed drives and similar components used by electromechanical engineers.

Readers are invited to submit constructive comments on the aims and purposes of Components Digest, as described above, as well as on the particular coverage of instrument servomotors presented in this first issue. Suggestions for future topics are invited, but please be specific.



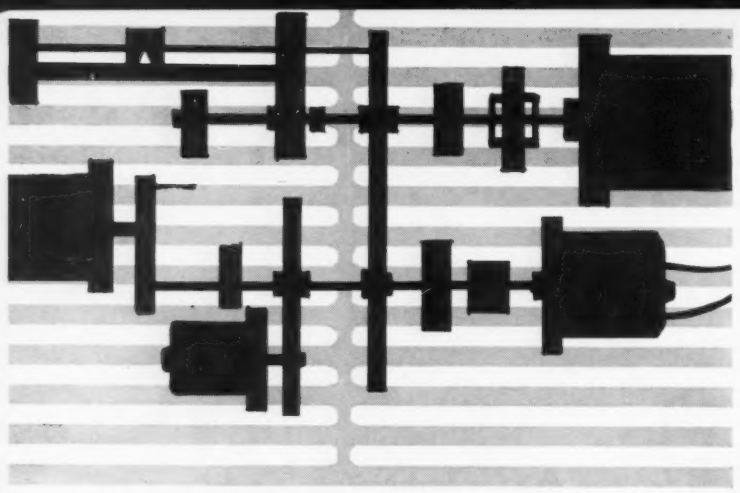
A-C Instrument Servomotors

In CD-1, the first issue of Components Digest, ELECTROMECHANICAL DESIGN covers the field of A-C Instrument Servomotors. Because of the wide scope of this field, and our objective of detailed coverage, the material is confined principally to motors having standard synchromount construction and rather general performance characteristics. The great variety of excellent but specialized motors require a different sort of treatment which can be more adequately handled in a separate Components Digest.

The organization of material leads logically from basic theory to a discussion of standards, a detailed tabulation of specific performance characteristics, and a buyers' guide. The uniform presentation of comparative information simplifies immensely the task of servomotor selection.

The motors listed in the tables are, without exception, production items, on which engineering is complete. They are designed to military requirements, are quite flexible in application, and are adaptable to the widest variety of application. The buyers' guide puts the application engineer directly in contact with the several manufacturers whose motors fit his requirements, for final discussion of specifications.

Unfortunately, the whole topic of induction generators, so intimately related to servomotors, must be postponed because of space limitations. We will cover this most important subject in the near future.



Basic Concepts for A-C Instrument Servomotor Application

Because of the special importance of two-phase servomotors, and the wide field they cover, it is necessary, in the interest of completeness, to restrict the scope of this material to small instrument servomotors of either standard or semi-standard types. The starting point for defining standard servomotors is the military specification MIL-S-17087 (Bu Ord) which defines ten types of two-phase, 400 cycle 115 volt, low inertia servomotors for use in light-weight precision equipment. These ten types are described in terms of sets of Bureau of Ordance drawings, as well as the military specification covering test procedures and performance. Environmental tests are essentially taken from MIL-E-5272 (USAF).

Since the standardization by the Bureau of Ordnance on certain specific types of servomotors, private industry has extended the general concepts beyond the Bureau's scope, principally in three directions:

- Additional frame sizes, in the direction of smaller units.
- More severe environmental conditions, particularly higher ambient temperatures.
- Improved performance.

It is in this last category that least progress has been made, since, in many respects, the Bureau's designs are nearly optimum for good, general purpose, easily-producible motors. However, a good deal of work is currently going on, with the object of getting more output at higher temperatures, with cost, for the moment, secondary.

The Standard BuOrd types are widely available from many manufacturers at attractive prices, considering the high quality of the units. Interchangeability is no particular problem. Units having essentially BuOrd performance, but with special voltage ratings (to match transistor amplifier outputs, for example) are also readily obtainable from many sources. Prototype prices may be somewhat higher than for standard BuOrd units but production prices are approximately the same.

As new insulations and lubricants become available, operating temperatures may be extended. Better materials coupled with sound manufacturing procedures permit most manufacturers to design for similar temperature ranges, notwithstanding the particular values specified in catalogs. The heat sink to which the motor may be mounted, the operating duty cycle, provision for cooling, the power ratings, and similiar factors determine the operating life of the motor over temperature extremes. Because standards do not exist, it is important, in critical applications, to pin down factors affecting motor temperature during its life, if a true comparison of manufacturers' claims is to be made.

Scope

The motors described here are the Bureau of Ordnance types plus the non-standard varieties that posses synchro-mount type outlines and cover the size ranges below the BuOrd sizes. Because little standardization exists as yet, other than in certain aspects of the outlines, motor data are often given as merely typical of what is available. Performance does not vary significantly as motors are rewound for different voltage ratings, while wattage ratings are maintained constant.

The material presented here references specific manufacturers in the case of unique designs. However, where many sources are available, no manufacturers are indicated.

Fig 1—Idealized Characteristics of two-phase servomotor as assumed by servo designer.

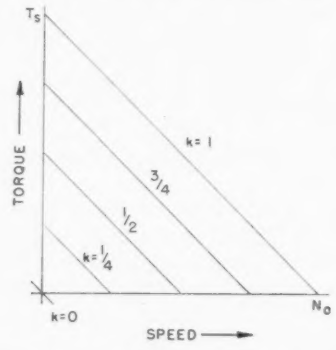


Fig 1(a)—Idealized speed-torque characteristics of two-phase servomotor for a number of values of control field voltage. Note the damping torque (opposing rotation) for k = 0.

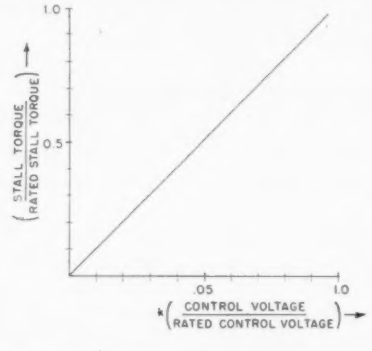


Fig 1(b)—Variation of stall torque with control voltage for idealized servomotor. This curve is almost always very well approximated in practice. For k = 1, saturation will flatten out the torque characteristic.

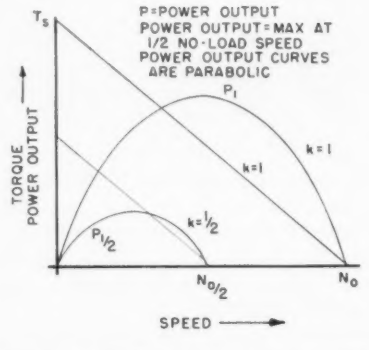


Fig 1 (c)—Variation of power output with speed for k = ½ and k = 1.

General Characteristics

The servo designer assumes certain ideal servomotor characteristics only approximately achieved in actual motors. In very small sizes, the approximation approaches the assumed ideal; in large sizes, design compromises, necessary in the interest of efficiency, cause substantial departures of the actual servo motor characteristics from the assumed ideal.

A servo motor may be considered as a two phase unit with the main phase excited from a fixed voltage source while the control phase is excited (for the moment, anyway) from a zero-impedance source having 90° phase shift from the fixed phase. Perfect balance is assumed in all respects except that the magnitude of the control field voltage may be considered as a variable. Second-order effects such as friction and non-linearities are ignored for the moment, and ideal performance is assumed.

The characteristics of Fig 1 show just what the servo designer expects. Fig 1 (a) shows a family of torque vs speed curves for various control voltages. Each individual curve applies to a fixed control field voltage. The curve of Fig 1 (b) shows stall torque vs control field voltage, and this is assumed to be a straight line, the basic linearity assumption of the servo motor. Fig 1 (c) shows the variation of power output for various fixed control field voltages as a function of speed. These last curves may be derived from the first ones, since power at any speed is proportional to the product of torque at the speed times the speed value itself.

Non-Ideal Characteristics of Very Small Servomotors

In very small servo motors, speed-torque curves are close approximations to straight lines. However, they are not a parallel set of uniformly spaced straight lines for varying control voltages. A good approximation is indicated in Fig 2. For lower control field voltages the slope of the speed-torque curve (or the damping, as will be discussed later) decreases. Servo designers who count upon the internal damping of the motor to stabilize their servomechanisms would be much concerned about this decrease in damping at low voltages. As a matter of fact, in a positioning servo, it is the operating point at zero control voltage and zero speed that is of most concern in considerations of stability, since here the secondary effects such as blacklash and potentiometer resolution tend to cause trouble. Fig 2b shows the slope of the speed-torque curve at stall, or the damp-

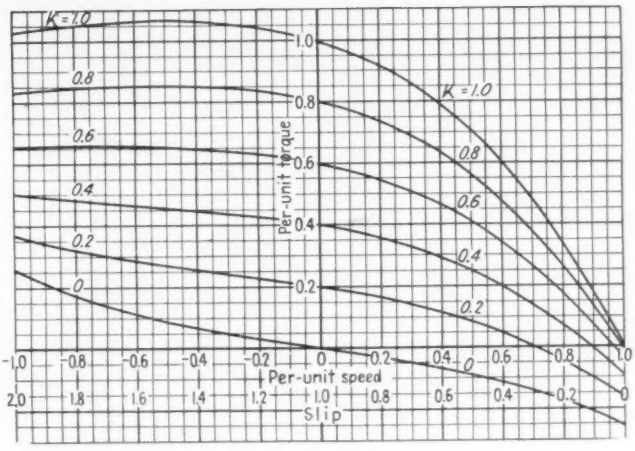


Fig 3—Torque-speed curves of a 2-phase servomotor.

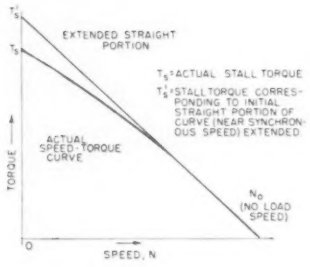


Fig 4—Determining zero-speed slope of speed curve by extending straight portion of curve.

$$\text{average damping} = \frac{T_s}{\text{no load speed}}$$

$$\text{actual stall damping (rated voltage)} = \text{average damping}\left(1-2\,\frac{T_s^1 - T_s}{T_s^1}\right)$$

$$\text{For } \frac{T_s^1 - T_s}{T_s^1} = \frac{1}{10}$$

$$\text{initial damping (at stall)} = [1-2(1/10)], \text{ or } 80\% \text{ of average damping}$$

Fig 2—Characteristics of small servomotor having essentially straight-line speed-torque curves. These characteristics are a much more accurate representation than those of Fig. 1.

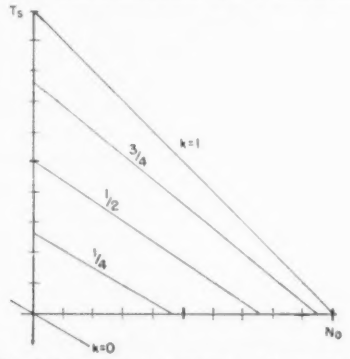


Fig 2(a)—Speed-torque characteristics of very small servomotor (small enough so curves are essentially straight). Slope of lines, or damping, varies as control field voltage varies. Accurately speaking, motor equations are nonlinear.

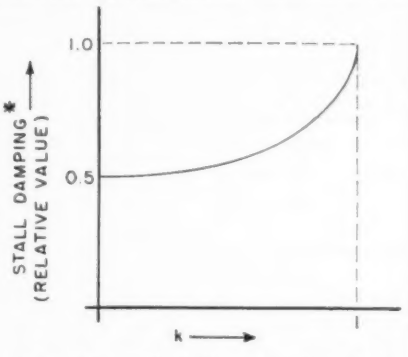


Fig 2(b)—Variation in damping characteristic as a function of control field voltage. The curve is parabolic with a minimum at k = 0. *Slope of speed torque curve at zero speed.

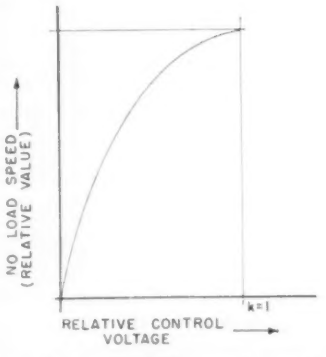


Fig 2(c)—Variation of no-load speed with control field voltage for a small servomotor having essentially straight speed-torque characteristics.

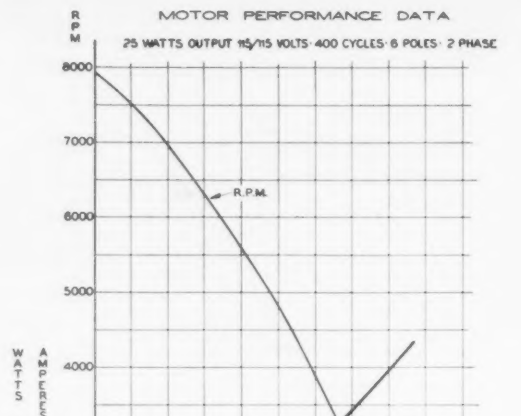


Fig 5a—Performance characteristics of a 400 cps servomotor rated for 25 watts output. (Motor No. S.S.FPF 49-19-1.)

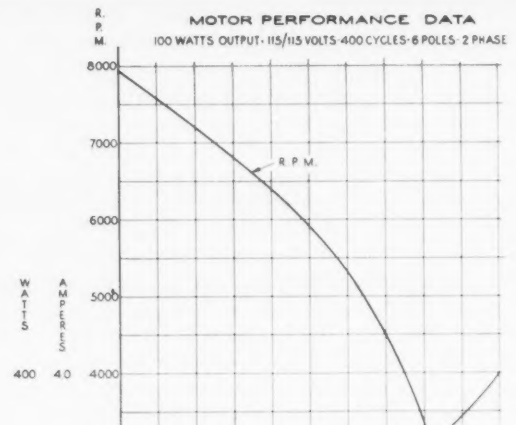


Fig 5b—Performance characteristics of a 400 cps servomotor rated for 100 watts output. (Motor No. S.S.FPF 85-16-1.)

Fig 5—The performance characteristics of these higher power Diehl servomotors show the highly curved speed-torque curve, which is a necessary compromise between good damping, and high efficiency. Motors like this must be excited on their control fields from a low impedance source, to avoid single phasing. Diehl is one of the few companies to make large two-phase servomotors, up to one horsepower.

ing at stall, for the assumed straight line characteristics. Damping at low control field voltages is about one half the damping at rated control voltage.

Stall torque even of the non-ideal motor is proportional to control field voltage. Variation of damping resulting in the non-parallel nature of the speed-torque curves results from non-linearity in the no-load speed vs control field voltage characteristic (Fig 2c). The information in this curve may be derived from the linear relationship between stall torque and control voltage, and the variation of damping as indicated in Fig 2b. The last curve illustrates how the motor tends to speed up very rapidly for low control field signals and then levels off in the vicinity of synchronous speed. This behavior makes for a higher velocity constant and a higher loop gain than might ordinarily be expected on the basis of theoretical design calculations.

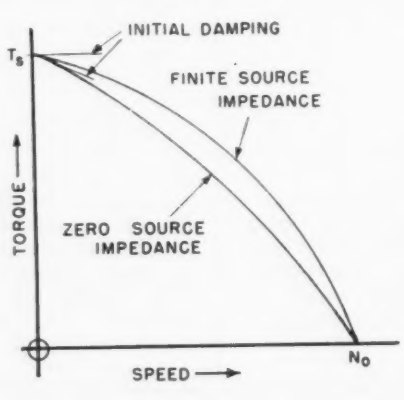


Fig 6—Effect of control phase source impedance on speed-torque characteristic.

Non-Ideal Features of Larger Servo Motors

Driving larger loads requires larger servomotors. Since a straight speed-torque characteristic comes from sacrificing efficiency, larger motors that deliver appreciable outputs require design compromises, balancing efficiency against linearity. Servo motor parameters must be adjusted for increased efficiency even at the cost of introducing curvature into the speed-torque characteristics. This curvature produces variable damping, with less damping available at slow speeds, detracting from the stability of the servomechanism containing the motor, and requiring additional servo stabilization.

Fig 3 contains a set of speed-torque curves for a typical moderate-power instrument servomotor with less than 2 to 5 watts of output power. Curvatures tend to be more pronounced for higher outputs. These curves show that the effective damping in a positional system equals the slope at zero control voltage and zero speed, which is half the initial slope of the balanced operation speed-torque curve. The initial slope is significantly less than the average slope which is commonly assumed by connecting stall torque and no-load speed. See Fig 4 for simple method of accurately determining initial slope. Thus, calculations based on average damping are apt to be in error by factors of three or four, or even more, one of the reasons for a large discrepancy between a theoretical servo design and the hardware that represents it.

Fig 5 shows the speed-torque curves that might be expected in motors of about 25 watts and 100 watts output. Servo motors are available up to about one horsepower in output. Heat problems in the larger motors are very severe, usually requiring a separate blower.

Dynamic Characteristics of Servo Motors

A servomotor must not only have the static characteristics described above, which include approximately linear speed-torque curves, but must in addition possess dynamic characteristics that enable it to follow changes in the control field signal accurately.

A servomotor must have low inertia. Because of its relatively high speed, servomotor inertia is frequently the largest single inertia in the system. Consequently, servomotors are apt to have long, small diameter rotors. A number of figures of merit define servomotor performance: Torque-to-inertia ratio, torque-to-square root of inertia ratio, theoretical stall acceleration, reversing time and time constant. Table III defines and discusses these terms. The parameters that are most significant depend upon the specific situation as described in Table III.

Application Problems

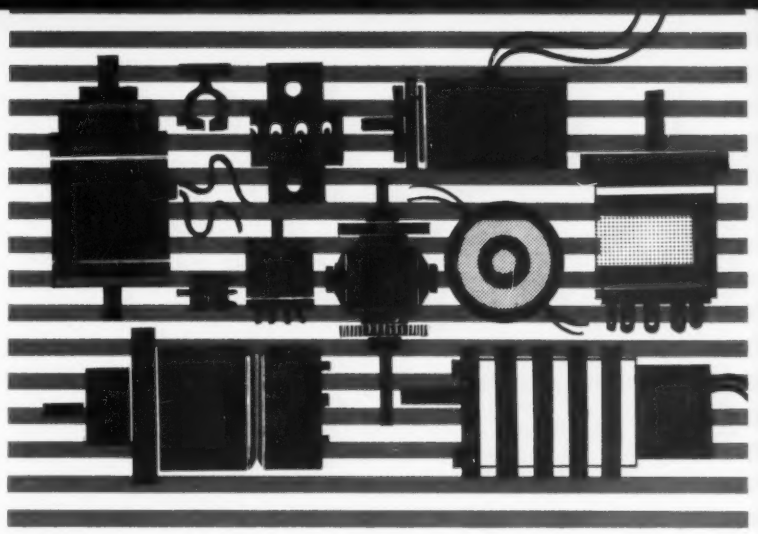
A number of performance limitations, other than departures from the ideal, characterize a servomotor. Consider single-phasing. Damping characteristics described above assume that source impedances exciting the motor windings are negligible. When control winding excitation is derived from a source having finite impedance, damping is reduced below the values for standard conditions. Fig 6 shows the effect of source impedance on the speed-torque curve. It is possible for servomotor damping under this condition to become negative, so that the motor runs with zero control field voltage. Where some appreciable curvature has been permitted in the speed-torque characteristic, larger motors may run on single phase, or exhibit *single-phasing*, where the control field excitation source differs appreciably from zero.

To test for single-phasing in small servomotors, the control field is opened while the motor is running at full speed. Damping is measured by the stopping time. This test is a particularly severe one, since an open control winding sharply cuts damping. For best results, a low output impedance amplifier should excite the control winding.

In larger motors, having appreciable curvature of the speed-torque characteristic, an open control winding may result in violent single-phasing. This condition is not necessarily a condemnation of the servomotor, since poorer damping was the price paid for better efficiency. However, designing the control field amplifier for a minimum output may achieve excellent damping.

If the control field winding is tuned for unity power factor and then excited from an amplifier having a high output impedance, then the motor reacts to the tuning capacitor as its control winding source impedance. This circuit aggravates single-phasing, so that a motor that has passed the standard tests may single-phase under this tuned condition. High output impedance often occurs with transistor amplifiers, which may act as current sources.

Servomotor sensitivity is measured by the voltage on the control winding that is just sufficient to start the motor. In a positioning system, this voltage is the key factor determining amplifier gain. Sensitivity is limited primarily by *cogging*. With the main field fully excited, the rotor tends to lock, due to magnetic forces. The number of distinct locking position matches the number of slots in the rotor. Cogging means that the motor cannot start unless the control field voltage generates enough torque to overcome the cogging. Cogging voltage is generally less than 3% of rated control field voltage. In addition to cogging, there are friction voltages which are measured as described later. Cogging plus friction tend to limit servomotor sensitivity, with cogging the largest factor.



Types of A-C Instrument Servomotors

STANDARD VARIETY MOTORS

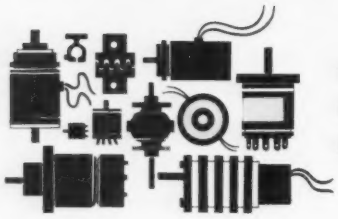
Standard-variety instrument servomotors have good general purpose performance characteristics with standard outlines; they are easily modified to suit different voltage and power ratings. Where required—usually at some sacrifice in the quality of servo characteristics—these units may be rewound for fewer poles, resulting in more mechanical power at the shaft but with a larger curve to the speed torque characteristics, poorer damping and a much higher motor time constant. Units of this type are more readily adapted to special environmental requirements. Modifications on shaft extension, mounting details and the substitution of leads for terminals are usually simple.

MOTORS FOR PLATE-TO-PLATE OPERATION

Motors may be wound such that the control fields may be energized directly from the plates of a push-pull output stage, or the transistor equivalent. This type of application requires three leads, two connected to the plates and the third to the B+ supply. This mode of operation eliminates the need for an output transformer, frequently the bulkiest and heaviest component of a miniature amplifier. Plate-to-plate operation normally improves the efficiency and quality of the output. As in conventional push-pull types of amplifiers, the motor control winding may be designed for d-c cancellations, in other words, no net d-c field in the motor. However, some net d-c will in general exist because of tube or transistor unbalance. This difference should be restricted to less than 10% of the quiescent plate current to avoid saturation and excessive losses as well as an additional—probably nonlinear—drag on the rotor. Motors of this type must withstand the dielectric stress imposed by the B+ voltage from the center-tap of the control winding to ground.

MOTORS WITH HIGH INTERNAL DAMPING

Some medium performance servomechanisms require high internal motor damping since no additional external damping can be applied to the system. In such cases a reduction in no load speed with negligible loss of motor stall torque may be achieved with slight design modifications. These modifications make the motor sensitive to internal harmonics in its flux fields which slow the motor down and consequently increase damping in the same proportion. Small instrument servomechanisms requiring negligible power with quality performance can best use this motor.



TYPES OF AC INSTRUMENT SERVO MOTORS, cont.

UNBALANCED POWER

To save control power, derived from a control amplifier and therefore expensive, motors may be designed to operate on unbalanced powers in the two phases. Assume that a motor operates continuously at stall with P watts total input with a safe temperature rise. Whereas in balanced operation there would be ½ watts per phase, it is possible to apply much less than ½ P to the control phase making up the total of P in the main phase without excessive loss in torque. Thus, if control power were ¼ P, and main power ¾ P, the torque would be 86.6% of the balance condition—a gain of 73.2% in the stall torque per control watt. The rule is: Torque varies as the square root of the product of the wattages. If the control field takes 10% of the total input power, the stall torque will only drop by some 40%. The reason: When rated voltages are applied to a motor designed for unbalanced operation, the phase powers will be unequal, the rated no load speed will decrease affectively increasing the damping. The square root of the ratio of control to main field powers may be regarded as a percent unbalance to be applied to fig 2c which shows the no-load speed to be expected.

However, some disadvantages accrue: the relatively heavy main field powers will increase cogging and therefore starting voltage; temperature rise for fixed total input power will increase as a result of the more concentrated main field dissipation; temperature rise will not drop off as significantly for a duty cycle in which control power is negligible as would be the case in a balanced motor, thus shortening the average life; noise will be greater and saturation problems may be encountered in the design. Nevertheless, where control power must be economized the use of unbalanced operation may prove valuable.

Where an absolute maximum of stall torque may be required, the main phase power may be substantially increased by an amount limited by heating and saturation. Doubling the main power with consistent control power, increases stall torque by approximately 41%. Standard 400-cycle motors are sufficiently unsaturated to permit taking advantage of the increased stator power. Additional heating resulting from the high main power may be taken care of by using high temperature lubricants and insulations or having a duty cycle where control power does not significantly add to the heating.

HIGH-TORQUE MOTORS

Higher torque may be required in a given BuOrd frame size to save space and weight, particularly in an otherwise marginal application. One answer is to pump in more watts, as described above under "Unbalanced Power." It is also possible to redesign the unit for more torque efficiency, say ,for example, by replacing the cast aluminum motor rotor with another having higher-conductivity copper bars. This construction is more costly, and results in less damping, even with increased stall torque, due to more curvature in the speed-torque characteristic. Single phasing might readily result. A motor that single phases may still provide good damping when the control phase is excited from an amplifier having negligible output impedance. Torques can be increased by 20-30% for a given total

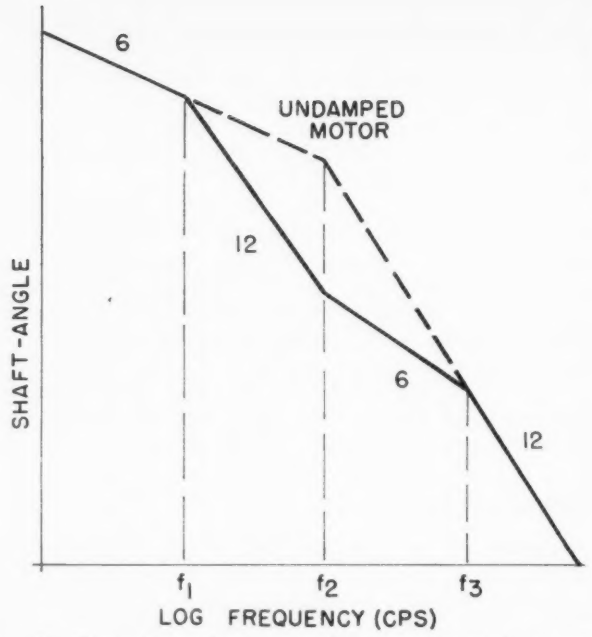


Fig 7—Typical performance data of inertial damped servomotors. These motors are similar to standard BuOrd types, but with specified break frequencies in the open loop dynamic characteristics.

Size	Basic Motor Type	f_1	f_2	f_3
11	BuOrd Mk 14	0.3	1.6	16
15	BuOrd Mk 7	0.3	1.2	28
18	BuOrd Mk 8	0.45	1.2	24

watts by using longer stacks of laminations. This type of "special" is relatively complicated to build, since new stator stack, housing, shaft, winding forms, and cast aluminum rotor (requiring special fixtures) must be made "special". However, there is nothing intrinsically costly that would boost production prices excessively. For an iron stack of double standard length, performance will approximate that of two standard motors, with slightly improved efficiency. Where length is at more of a premium than diameter, use shorter than standard iron lamination stacks.

HIGH-ACCELERATION MOTORS

The rotors of the standard and semi-standard servomotors vary from ½ inch in the size 18, to ¼ inch in some versions of the size 8. Inertia for a given length of rotor varies as the fourth power of the diameter, so the ½ inch rotor will have 16 times the inertia per unit length of the ¼ inch rotor. It is feasible to design a servomotor with a relatively small rotor that may cut the torque-per-watt-input efficiency, but at the same time sharply increase the theoretical stall accelerations of more than 100,000 rad per sec^2. For example, see performance data for motors by Helipot in Chart CD-I-1.

MOTORS WITH MAIN FIELD CAPACITOR

A capacitor is frequently used in the main field of a servomotor to achieve the required 90° phase shift between main and control field signals. This 90° shift is set at stall conditions. The motor winding is so designed that when the 90° shift is achieved by adjustment of a series-capacitance, the wattage drawn by the winding is standard value. In small motors this method works very satisfactorily where it is inconvenient to shift the control field voltage phase. Such phase shift may be impractical, for example, with certain magnetic amplifier excitation circuits. In the larger BuOrd motors, problems occur as a result of

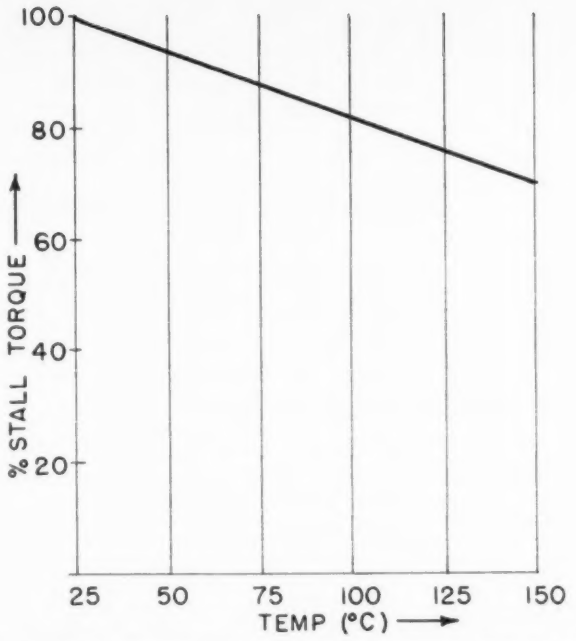


Fig 8—Approximate effect of winding temperature on stall torque, showing loss in motor torque at high temperatures.

the changing motor impedance with speed. Voltage across the main winding tends to go up, resulting in more torque and power. Considerable heating may occur at no load. The internal damping becomes inferior. This affect becomes more pronounced at increased frequency (400 cycles as compared with 60 cycles) fewer poles (faster motors) and in larger motors. A standard motor may be used with a series-capacitance phase shift network by employing two capacitors, one directly across the motor control phase, and the other in series with the line. By using this arrangement with the motor stalled, and adjusting the two capacitors individually, it is possible to achieve the required 90° phase-shift at the correct power rating. Sometimes a similar result may be achieved by a series-capacitor-resistor combination in the main field.

VISCOUS DAMPED MOTORS

Where relatively low output power with excellent damping are required, a magnetic viscous damper coupled directly to the back of a servomotor constitutes an especially convenient combination. In most commercially available models, a screw driver adjustment and locking device are provided to permit setting the damping at a required value. This permits simple laboratory determination of required damping and available margins. Where maximum damping is required, it is preferable to have this setting made permanently at the factory since the maximum damping of an adjustable unit is often less than for a fixed unit, because of the properties of the permanent magnet in the damper. Viscous damping directly at the motor shaft is especially effective in damping out oscillations resulting from backlash, end-play, and similar nonlinearities, and at the same time does not complicate the wiring or introduce electrical noise. On the other hand, the viscous damper does subtract from the available shaft power. Structurally, the viscous damper is essentially a low inertia aluminum cup on the motor shaft made to rotate a permanent magnet field fixed to the motor frame. The viscous drag is generated as a result of the eddy currents of rotation induced in the cup. The drag varies with temperature in much the same way that the cup conductivity varies, namely about 20% for a 50°C temperature change. Torque decreases at higher temperature.

Viscous damped motors are available in BuOrd Size-11 frame and standard performance, with damping typically of 150 dyne-cm-sec per radian, cutting no-load speed to about 3000 rpm, without loss of stall torque.

INERTIALLY DAMPED MOTORS

Inertially damped motors are combinations of conventional servomotors with special built-in damping devices in one integral assembly. These dampers are superior to straight viscous dampers in that they do not subtract from the velocity of the servomotor or reduce available mechanical output power at the motor shaft. Structurally, they consist of a drag-cup of conducting material rigidly connected to the motor shaft, and a magnetic structure mounted on frictionless bearings, also on the motor shaft. During transients, viscous-type damping is generated as a result of relative motion between the drag-cup and the massive magnetic structure which does not respond quickly to sudden transients. However, during slewing or constant velocity operation, the magnetic structure eventually accelerates to the same speed as the drag-cup and, except for the loss in the bearing that supports the magnetic structure, there is no reduction in motor speed or power.

Inertially damped motors permit the design of stable servomechanisms with band-widths out to 25 cps and more. On the negative side, inertial dampers introduce substantial errors during accelerations. Step function response is characterized by a large initial overshoot, which, however, quickly attenuates. For slowly accelerating servomechanisms requiring high velocity constants, they are excellent.

MOTOR-TACHOMETERS

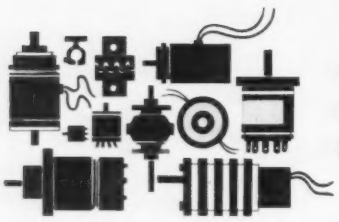
For convenience and superior performance, integral assemblies of motors and tachometer generators are commonly used. Although the performance characteristics of tachometer generators are not within the scope of this presentation, they do constitute an important area of application.

The two principal varieties of tachometer generators are those used in precision circuits requiring accurate control of velocity or the integration of electrical signals, and those lower-accuracy tachometers that are used for damping. (The characteristics of these types of generators will be described in a later issue of Components Digest.) Damping generators are widely used and constitute an extremely effective and flexible method of damping, especially in high-gain positioning servomechanisms. The principal disadvantages are: higher cost, more complex wiring, the introduction of electrical noise, greater physical length, and the lag errors they introduce in servomechanisms going at uniform velocities.

Analytically, tachometer damping is equivalent to viscous damping. However, there is no loss in available shaft power with tachometer damping, and the full mechanical output of the motor is available for high-speed slewing.

GEARHEAD MOTORS

A good deal of system simplification results from using servomotors with built-in gearheads. Not only does the use of these components result in substantial manufacturing economy, but simultaneously yields thoroughly-engineered, environment-proof, compact packages. Miniature gears add minimum additional inertia. Design time is saved. Commercially available gearheads for instrument servomotors generally come in a fixed basic design, allowing changeable gear clusters. This permits many reduction ratios readily available by assembly of stock gears. Since the individual gear types required to achieve most practical ratios are not very numerous, great manufacturing economy and rapid



TYPES OF A-C INSTRUMENT SERVO MOTORS, cont.

delivery are affected. However, where special ratios are required having *exact* values, a special design may be required at much higher cost. Designs are available incorporating spring-loaded gears for zero backlash, and slip clutches to limit impact forces during servo transients. Backlash is normally under about 30 minutes although 20 and even 15 minutes are available on special request. Environmentally, gearhead motors can withstand the most stringent military specifications.

Very often, output capacity of a servomotor is limited, not by the ability of the motor to deliver torque, but rather by the ability of the gearhead to transmit the high output torques reliably. Thus, a motor with about 1 oz-in of stall torque through a 100:1 ratio would develop a stall torque of 100 oz-in on the output shaft. Such a motor may not be allowed to stall unless the gearhead can withstand such high torques. High torques may be necessary in the motor for purposes of acceleration, even though such torques are not required at the output of the gearhead.

Special Data on Gearhead Motors

There are a number of reliable suppliers of precision gearheads for the miniature servomotor manufacturer. The variety of gearheads they produce is very great since many of the types were originally designed for special purpose applications. Emphasis on low cost, minimum length, high temperature operability, offset output shaft, or some other special requirement led to the development of this variety.

TABLE OF GEARHEAD CHARACTERISTICS[1]
(Approximate Values)

Size	Length[2] inches	Operating Load Torque oz-in	Maximum Momentary Load Torque oz-in	Backlash min
8	1.044	5	25	30
10	1.197	12	50	45
10	0.906	12	50	45
11	1.475	25	100	30-45
15	1.610	35	100	30
18	1.627	65	150	30

[1]The specific values listed, though typical for the frame sizes and generally available from a number of sources, are for the Bowmar Instrument Corp. gearheads, which are an inclusive line.

[2]Shorter lengths are provided for low ratios having fewer clusters.

Notes:
1. Inertia of gearhead motors is negligible in comparison with that of standard servomotors.
2. Slip clutches may usually be incorporated.
3. Starting torques of gearheads at no load are within limits such as not to reduce servomotor sensitivity to control field voltages significantly.
4. A great variety of standard ratios is available. Special ratios are more expensive and require longer delivery time.

Some gearheads are designed to be readily mounted with standard hardware directly to servomotors having BuOrd-type front ends. Others are designed for integral assembly with the servomotor. Where high output torques are required, output gear stages must be strengthened accordingly. Gearheads duplicate the standard motor synchro-mounts for the frame sizes.

The data below is typical of gearheads which are generally available commercially. "Specials" cost a great deal more in prototype quantities, but are only slightly higher in large production quantities. Price and delivery of a prototype gearhead servomotor often depends predominantly on the gearhead.

HIGH TEMPERATURE MOTORS

A number of manufacturers are currently working on motors for much higher ambient temperatures than are called for by current military specifications. Requirements at these high temperatures are tentative, based upon preliminary specifications and what manufacturers can actually achieve. Experimental motors have been run for limited periods at temperatures as high as 1000°C. However, the immediate target is more in the vicinity of 500° to 600°F. High temperature motor design requires attention to three major areas.

- Dimensional stability, matching temperature coefficients, avoiding mechanical interference in the air gaps.
- Insulation and lubrication.
- Controlling the degradation in performance that occurs very naturally at high temperatures, see Fig. 8.

The quality of materials, the control of tolerances, and the complex details of manufacturing and testing out make high-temperature motors up to many times more costly than their low temperature counterparts.

Since life depends very sharply on motor temperature, attention must be paid to methods of mounting (a heavy heat-sink is naturally best), cooling, duty cycle, and required output. Because hot and cold temperature design requirements sometimes conflict (as in specifying lubrication), you must know cold temperature requirements.

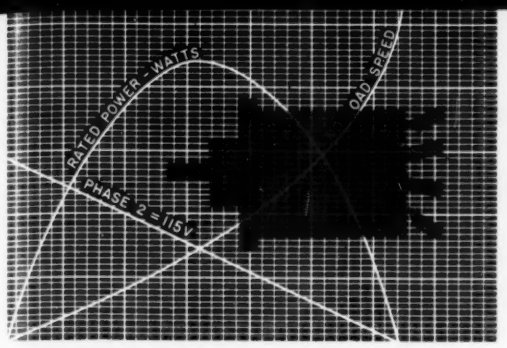
Current best commercial practice is, very roughly, several hundred hours of life in a mounted motor at rated output in a 180°C ambient. This figure varies very widely, however, depending on exact conditions.

DRAG CUP MOTORS

Drag cup motors have extremely high sensitivity, since the rotating member has no iron. Typical starting voltages are of the order of ½% of rated control voltage, about 6 times standard sensitivity. However, stall torque per watt is about ½ the value for conventional motors.

MOTOR PACKAGES

To achieve even further compactness and simplicity motors are frequently designed into more or less standard packages, which may be used in one or more places in a system as a single component. Such packages frequently contain a motor, gearing, data elements such as potentiometers or synchros, and recently, even amplifiers. Manufacturers are now providing complete servos, in compact, easily installed, motor-like packages which vastly simplify the packaging and maintenance of equipment. It will, however, be a long time, if ever, before universal agreement on standards of this type can be achieved. Even straight servo-amplifiers cannot satisfy the great variety of packaging and performance requirements in standard form. A later issue of Components Digest will cover packages of this type, in detail.



SERVOMOTOR STANDARDS

Original work by the Bureau of Ordnance, as covered in MIL-S-17087 (BuOrd), was a major advance in the improvement and standardization of servomotor. In the interests of expansion of this work for very small sizes, and more stringent environmental requirements, the SAE has sponsored meetings of all important manufacturers of servomotors for standardizing a specification. The resulting specification, ARP497, "Precision Control Motors", is still in draft stage. It represents the best combined thinking on the subject of servomotor standards, and bears close watch by users as well as manufacturers. Many motors are not standard except in mounting dimensions. To some extent they represent manufacturers' attempts to *anticipate* standards. Table II, from ARP497, is currently the closest approximate to a standard specification. There are motors available with similar specifications, but numerous deviations exist.

The SAE has made an important contribution by taking into account the effect of warm-up on the impedance and torque of the servomotor. A servomotor with an ultimate temperature rise under standard test conditions of 65°C will vary its behavior during warm-up period. To clarify what a given set of performance characteristics signifies the SAE has defined performance both in terms of the hot steady-state condition and the cold (room temperature) condition. The latter is the logical condition for economical production testing.

In general the BuOrd specifications have come environmentally, under MIL-E-5272A. New specifications for higher temperature operation, and resistance to neutron radiation, are being compiled for ultimate standards. The SAE also covers the environmental tests, but these are not repeated here.

STANDARD DEFINITIONS Proposed by SAE in ARP 497

MECHANICAL

Perpendicularity of Mounting Faces. The total maximum difference between high and low readings of a dial indicator suitably arranged to denote the out-of-squareness relation of the mounting surface at a specified distance from the O.D. of the motor with respect to the rotational axis of the shaft when the housing is rotated about its fixed shaft.

Run-Out of Smooth Shaft or Pinion. The maximum difference between the high and low reading of a dial indicator suitably arranged to measure eccentricity of the smooth shaft or pinion pitch diameter at a point ⅛ inch from its end when rotated in its own bearings with the body held stationary.

Run-Out of Mounting Diameters. The maximum difference between the high and low readings of a dial indicator suitably arranged to measure the eccentricity of the mounting diameters with respect to the rotational axis of the shaft.

Radial Play. The maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total radial travel (sum of both directions) of the shaft in its own bearings. It is measured ⅛ inch from the extreme forward surface of the housing, upon reversal of a specified radial load applied at the same distance from the housing.

End Play. The maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total axial travel of the shaft in its own bearings upon the reversal of a specified axial load. This measurement to be made with motor shaft horizontal.

ELECTRICAL

Control Voltage Winding. The motor winding which is excited by a varying voltage at a time phase difference from the voltage applied to the fixed voltage winding.

Fixed Voltage Winding. The motor winding which is excited by a fixed voltage.

Center Tap Winding. An internal tap at the center of a winding. (3 external leads.)

Split Winding. An equal division of a winding which will allow series or parallel external connection of the divided winding (4 external leads.)

No Load Speed. The speed of the shaft rotation with no load applied to the shaft and rated voltage and frequency with proper phase relationships applied to both windings.

Stall-Torque. The torque developed at speeds in excess of 1 rpm but less than ½ percent of synchronous speed with rated voltage and frequency of proper phase relationship applied to both windings.

Minimum Starting Voltage. The minimum voltage of rated frequency applied to the control voltage winding necessary to start the rotor turning at no load conditions with rated voltage and frequency on the fixed voltage winding.

Slot Effect. A variation of magnetic interlocking between the rotor and stator.

Single Phasing. The tendency of the rotor to continue to rotate when one winding is opened and the other winding remains excited.

Time Constant. The time required for the motor to accelerate from 0 to 63.2% of its final no load speed when rated voltage, with proper phase relationship, is applied.

Theoretical Acceleration at Stall. A figure of merit derived from the stall-torque-to-rotor-inertia ratio which indicated how rapidly a motor will accelerate from stall.

Effective Resistance. The equivalent pure dc resistance which when substituted for the winding being checked will draw the same power. It is also equivalent to the impedance of a circuit with a capacitor connected in parallel with the winding and the capacitor adjusted to unity power factor for the circuit.

Table I. DIMENSIONAL CHART FOR FIGURE 9 • All Dimensions in Inches

Size	A ±.031	B +.003 −.010	C	D +.0000 −.0005	E Shaft Detail (Pinion Data)-Pressure Angle 20 a	+.0000 b −.0005	c	d	Smooth Shaft +.0000 d −.0005	F Max. Lth.	G ±.0
7	.375	0.625	None	0.5000	120	0.0666*	8	.0906 −.0901	.0906	1 1/2	0.0
8	.375	0.750	None	0.5000	120	0.1083*	13	.1247 −.1242	.1200	1 5/8	0.0
9	.375	0.900	None	0.5000	120	0.1083*	13	.1247 −.1242	.1200	1 3/4	0.0
10	.375	0.937	0.8123 −. 8118	0.5000	120	0.1083*	13	.1247 −.1242	.1200	1 3/4	0.0
11	.375	1.062	1.0000 − .9995	0.6250	120	0.1083*	13	.1247 −.1242	.1200	1 7/8	0.0
15	.437	1.437	1.3120−1.3115	0.8750	96	0.1562*	15	.1796 −.1786	.1200	2	0.0
18	.562	1.750	1.5620−1.5616	0.9375	96	0.1562*	15	.1796 −.1786	.1200	2 3/8	0.0
20	.562	2.000	1.8750−1.8745	0.9375	96	0.2291	22	.2490 −.2480	.1875	3 3/8	.00
23	.562	2.250	2.0000−1.9990	0.9375	96	0.2291	22	.2490 −.2480	.1875	4	0.0
25	.562	2.478	2.3130−.31200	0.9375	96	0.2291	22	.2490 −.2480	.1875	4 1/2	0.0
28	.562	2.781	None	0.9375	96	0.2291	22	.2490 −.2480	.1875	4 1/2	0.0
34	.625	3.375	3.1250−3.1240	1.3120	64	0.2656	17	.2970 −.2960	.1875	4 7/8	0.0

a. Diametral Pitch *b. Pitch Diameter* *c. No of Teeth* *d. Outside Diameter*

Table II. TENTATIVE SAE STANDARD INSTRUMENT SERVOMOTORS

Size	No. Poles	Max Starting Voltage % of Rated	Min No Load Speed rpm	Min Stall Torque in oz	Max Speed at 1/2 Stall Torque rpm	Min Watts Output	Max Temp Rise °C	Max Watts Input Per Phase	Nominal Condenser to tune to Unity P. F. mfd	Max Moment of Inertia gm-cm	Rated Voltage Fixed Voltage Winding	Rated Voltage Control Voltage Winding
7	4	3.0	8800*	0.063[3]	7200	.1*		1.25*		.7	26	26
8	6	3.0	6200	.33	4800	.40	65	3.8	1.5	1.3	26	26
9	6	3.0	6200	.30	4800	.365	55	2.75	1.4	1.3	26	26
9	4	3.0	9800	.225	7200	.40	55	2.75	1.0	1.3	26	26
10	6	3.0	6200	.275	4800	.35	65	3.1	2.0	.7	26	26
10	4	3.0	9800	.25	7200	.45	65	3.5	2.0	.7	26	26
11	6	2.6	6200	.55	4800	.70	60	3.9	.14	1.3	115	115
15	4	2.6	9800	.95	7200	1.8	70	6.8	.21	3.9	115	115
15	8	2.6	4800	1.3	3600	1.3	70	6.8	.32	3.9	115	115
18	4	2.6	9800	1.4	7200	2.72	70	9.9		4.8	115	115
18	4	2.6	9800	2.4	7200	4.9	70 Fix φ only	19.8	.60	4.8	115	115
18	8	2.6	4800	2.1	3600	2.1	70	9.9	.55	4.8	115	115
23	4	2.6	9800	3.65*	7200	8.0*	65*	8.0*	.61	19	115	115
23	8	2.6	4800	4.4	3600	6.9	75	16.5	1.04	13	115	115
28	4	2.6	9800	22.8*	7200	54*	93*	120*	5.0	49	115	115

Impedance data to be included and table enlarged to include all standard voltages at conclusion of impedance measurement testing being conducted by the SAE Committee A-2 Precision Control Motors Standardization Panel in cooperation with the Bureau of Standards.

** Nom.*

*** Values are for standard conditions.*

Inches Unless Otherwise Specified

H .005	I ±.005	J Min	K Max	L Min	M Max	N ±.003
None	0.062	0.045	0.550	None	0.640	None
None	0.062	0.045	0.670	0.25	0.765	None
None	0.062	0.045	0.820	0.25	0.915	None
.062	0.062	0.045	0.840	0.25	0.952	None
.062	0.093	0.045	0.980	0.25	1.080	0.812
.132	0.093	0.073	1.317	0.312	1.455	1.100
.132	0.093	0.073	1.630	0.437	1.768	1.250
.200	0.125	0.095	1.880	.....	2.018	None
.200	0.125	0.095	2.067	.....	2.268	None
.200	0.125	0.095	2.313	.....	2.496	None
None	0.421	0.125	2.600	.....	2.799	None
.281	0.219	0.156	3.195	.....	3.393	None

Modified Tooth Form

DIMENSIONS OF PROPOSED STANDARD SAE SERVOMOTORS

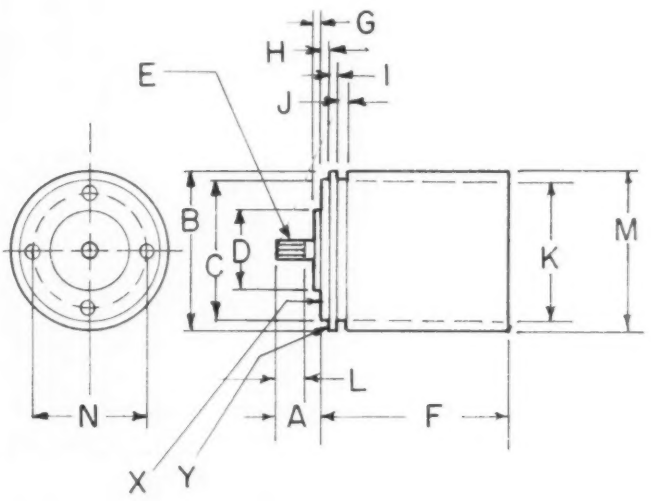


Fig 9—Dimensions of Proposed Standard SAE Servomotors. No 4 (0.112)-40 NC-2 thread. 4 Holes equally spaced ±0.003 on "N" diameter. Minimum screw engagement of 3 full threads with clearance provided for a minimum of 0.125 inch depth of screw engagement. Maximum recommended depth of penetration of mounting screws is 0.109 to insure against damaging windings. Length "F" is maximum for unit with either flexible leads or terminal assembly, leads for terminal block to be located on face opposite mounting. Length "L" is length of full depth of pinion.

NOTE: Pinions to be precision Class 1 per ASA B6.11-1956 (AGMA 236.04), and designed per ASA B6.7-1956 (AGMA 207.04). Enlarged C.D. of 13 tooth, 120 pitch pinions is reduced after cutting to permit use of ⅛ inch I.D. bearing. Hardness to be greater than 28 Rockwell on "C" scale.

- **End Play measurements should be as follows:**

Size	Load-Ounces	End Play Inches Max
7 thru 11	3	0.005
15 thru 18	16	0.005
20 thru 34	16	0.015

- **Runout measurements should not exceed 0.0015-inch F.I.R. for pinions and 0.001-inch F.I.R. for smooth shafts.**

- **Runout measurements should not exceed 0.001 F.I.R. Radial Play measurements should be as follows:**

SIZE	LOAD-OUNCES	Radial Play INCHES MAX
7 thru 18	8	0.001
20 thru 34	16	0.001

Perpendicularity measurements made within 0.062 inch from O.D. of surface "X" and/or "Y" to shaft should not exceed 0.001 F.I.R. for sizes 11 and smaller or 0.001 per inch O.D. for sizes larger than 11.

Surfaces "X" and "Y" should be flat within 0.001 inch per inch.

Interpreting Charts CD-I-1 and 2

The charts of servo motor characteristics are not intended as a basis for comparing manufacturers. Some manufacturers present data on specific models, regardless of whether they are optimum designs or not; others present typical data representative of a variety of models they manufacture. Some present maximum performance, etc. In general manufacturers who are tooled up for particular frame sizes do equally well in the performance they are capable of achieving in their designs, even for conditions of environmental extremes, including temperature. There are not many real design secrets. The differences are in quality, delivery, and price, the areas that most interest purchasing departments.

Note stall-torque capabilities. In this area compare units of equal wattages and essentially the same length. The wattages for the various frame sizes for approximately equal temperature rises are:

SIZE	8	10	11	15	18
WATTS	1.8	2.8	3.5	6.1	9.1

These wattages introduce a 65° C rise when the motors are mounted on standard aluminum plates.

Rotor inertia occurs in discreet values. Since the manufacturer of small precision servomotors grinds the stator I.D. and bearing seats in one operation to insure concentricity, rotor diameters correspond to bearing sizes. For various rotor diameters, with approximately ¾ inch of active length, the inertias are:

⅝" *diam*	*10 gm-cm²*
½" *diam*	*3 gm-cm²*
⅜" *diam*	*1 gm-cm²*

Servomotor characteristics charts CD-I-1 and 2 are on the following two pages

CHART CD-I-1

SUMMARY OF INSTRUMENT SERVOMOTORS

AVERAGE MECHANICAL CHARACTERISTICS

Ref No	Freq (cps)	Size	Mfgr ⑥ by code	Weight (ozs)	Length ② (inches)	Rotor Inertia (gm-cm²)	Stall Torque (oz-in)	Internal Damping (Dyne-cm-sec)	No Load Speed (rpm)	Time Constant (sec)	Reversing Time Approx (sec)	Temp Range ③ (degrees C)	Theoret Accel at Stall (rad/sec²)
1	400	8	P	1.0	.....	0.46	0.10	10.9	6,500	.0421	.0711	.....	.....
2	400	8	N	1.6	1.240 Max	1.07	0.33	35.9	6,200	.030	.051	.....	21,800
3	400	8	N	1.0	0.820 Max	0.46	0.10	10.9	6,500	.0422	.071	.....	15,400
4	400	8	Q	1.5	1.00	0.414	0.22	22.8	6,500	.0182	.0307	—55 to +204	37,600
5	400	8	R	1.2	0.863	0.47	0.15	15.6	6,500	.030	.051	—54 to +125	22,500
6	400	8	D	1.5	0.953	0.5	0.20	21.8	6,200	.023	.0388	—55 to +120 ⑤	.....
7	400	8	H	1.5	—1.00	0.50	0.15	16.1	6,300	.0311	.0525	—55 to + 71	21,000
8	400	8	L	1.1	0.840	0.10	0.25	28.1	6,000	.00356	.006	Max 130	170,000
9	400	8	L	1.6	1.165	0.20	0.33	37.0	6,000	.0054	.00913	Max 130	115,000
10	400	8	I	2.5	1.241 Max	1.1	0.30	32.3	6,500	.036	.061	Intermt. @ stall	20,600
11	400	8	C	1.04	0.828	0.38	0.15	15	6,500	.022	.0372	—55 to +125	28,000
12	400	8	C	1.68	1.172	1.0	0.30	30	6,500	.030	.051	—55 to +125	21,000
13	60	11	D	4.5	1.500	1.2	1.0	211	3,200	.0057	.0096	—55 to +120 ⑤	59,000
14	400	9	D	2.75	1.250	1.0	0.3	32.7	6,200	.030	.051	—55 to +120	21,300
15	400	10	X	1.45	0.828	0.46	0.30 Min	32.3	6,500	.0153	.0260	—54 to +100 ⑤	49,000
16	400	10	R	2	0.672	0.47	0.30	32.3	6,500	.015	.025	—54 to +125	45,000
17	400	10	Q	1.45	0.928	0.46	0.30 Min	32.6	6,200	.0153	.0258	—55 to + 71	46,000
18	400	10	C	1.43	0.968	0.38	0.30	26.5	6,500	.014	.0237	—55 to +125	55,700
19	400	10	C	2.32	1.165	1.0	0.60	52	6,500	.016	.027	—55 to +125	50,000
20	400	10	K	1.8	0.922	0.7	0.30	32.3	6,500	.0217	.0367	.....	30,000
21	60	11	F	.....	1.500	1.4	0.73	300	1,450	.005	.0085	—55 to +204	35,000
22	400	9	D	2.75	1.250	1.0	0.25	16.2	10,000	.062	.0105	—55 to +120	17,700
23	400	11	X	4.5	1.745	1.07	.60	64.5	6,200	.0168	.0268	—54 to +120 ⑤	39,500
24	60	15	D	7.5	1.703	3.2	2.0	421	3,200	.0076	.0129	—55 to +120 ⑤	44,100
25	60	15	Q	8.5	1.766	3.3	1.45	306	3,200	.0119	.0202	—55 to + 95	31,000
26	60	15	Q	7.3	1.641	3.3	1.3	548	1,600	.0606	.103	—55 to +100	27,800
27	60	15	Q	8.5	1.766	3.3	1.45	306	3,200	.0119	.0202	—55 to + 90	31,000
28	400	15	X	7.3	1.657	3.3	1.53	195	5,300	.0169	.0287	—54 to +128 ⑤	32,600
29	400	15	D	7.5	1.453	3.2	0.95	64	10,000	.050	.0845	—55 to +120 ⑤	21,000
30	400	15	L	8.0	1.375	1.00	1.45	163	6,000	.00614	.0104	Max ..120	100,000
31	400	15	Q	7.3	1.641	3.3	0.95	64	10,000	.0258	.0436	—55 to + 85	20,700
32	60	18	N	12.2	2.031	4.0	3.48	742	3,400	.00584	.00993	—54 to +120 ⑤	61,500
33	60	18	D	15.5	1.953	3.6	4.0	845	3,200	.00426	.0072	—55 to +120	78,500
34	60	18	Q	12.2	2.000	3.5	2.35	495	3,200	.0071	.0120	—55 to + 70	47,500
35	400	18	X	12.2	2.044 Max	4.0	2.4	312	4,800	.0131	.0223	—54 to +150 ④	39,700
36	400	18	N	12.2	2.031	4.0	2.8	204	9,800	.0207	.0353	—54 to +120 ⑤	47,800
37	400	18	D	15.5	1.766	3.6	3.0	213	10,000 Min	.017	.0288	—55 to +120 ⑦	58,700
38	400	18	D	15.5	1,766	3.6	1.45	103	10,000 Min	.035	.0591	—55 to +120	28,400
39	400	18	Q	12.2	2.000	3.5	1.8	124	9,800	.0279	.0471	—55 to + 70	36,000
40	400	5	H	0.94	1.297	0.22	0.11	7.8	9,500	.0282	.0476	—55 to + 70	35,000

Footnotes

1. For series connection, where alternate parallel connection exists. Variety of control voltages generally available.
2. Defined only approximately; varies depending upon exact details of construction and points of measurement.
3. When not indicated, temperature range usually can be made to meet typical requirements. Discuss directly with manufacturer.
4. When total ambient + motor rise does not exceed 165° C.

CHART CD-I-2

SUMMARY OF INSTRUMENT SERVOMOTORS

AVERAGE ELECTRICAL CHARACTERISTICS

Ref No	Z Main Windings (ohms)	Z ① Control Windings ohms()	Voltage ① Fixed Phase (volts)	Voltage Control Phase (volts)	Current Fixed Phase Stall (amps)	Power Fixed Phase Stall (watts)	Power Factor Fixed Phase Stall	Current Control Phase Stall (amps	Power Control Phase Stall (watts)	Power Factor Control Phase Stall	Parallel ① Tuning Condenser for Unity P. F. at Stall (mfd)	Effect Resist Stall (ohms)	Theoret Accel at Stall (rad/sec²)
1	287 +j 178 = 338	Same	26	26	.077	1.7	.85	.077	1.7	.85	.62	398	21,800
2	135 +j 98 = 166	Same	26	26	.157	3.4	.840	.157	3.4	.840	1.3	198	15,400
3	173 +j 100 = 200	Same	18	18	.090	1.5	.866	.090	1.5	.866	1.0	230	37,600
4	200 +j 200 = 283	Same	28	26	.092	1.72	.700	.092	1.72	.700	1.0	407	22,500
5	196 +j 183 = 268	480 +j 445 = 660	26	40 / 20	.097	1.86	.73	.0607	1.78	.73	0.4	910	.....
6	240 +j 194 = 308	Same	26	26	.084	1.7	.779	.084	1.7	.779	0.81	395	21,000
7	158 +j 104 = 190	Same	18	18	.095	1.5	.83	.095	1.5	.83	.....	.....	170,000
8	96 +j 138 = 168	228 +j 328 = 400	26	40 / 20	.155	2.3	.57	.100	2.3	57	0.82	700	115,000
9	1270 +j2030 =2400	Same	115	115 / 57.5	.048	2.9	.53	.048	2.9	53	0.14	4500	20,600
10	131 +j 91 = 160	Same	26	26	.163	3.1	.82	.163	3.1	.82	1.4	193	28,000
11	173 +j 178 = 248	Same	26	26	.105	1.9	.695	.105	1.9	.696	1.15	357	21,000
12	124 +j 120 = 173	Same	26	26	.150	2.8	.718	.150	2.8	.718	1.6	241	59,000
13	171 +j 131 = 215	Same	26	26	.121	2.5	.795	.121	2.5	.795	1.125	270	21,300
14	135 +j 136 = 191	Same	26	26	.136	2.5	.705	.136	2.5	.706	1.5	270	49,000
15	98.5 +j 123 = 157	Same	26	26	.166	2.7	.63	.166	2.7	.63	2.0	250	45,000
16	1270 +j1560 =2210	124 +j 215 = 248	115	40 / 20	.052	3.44	.57	.161	3.22	.50	1.4	495	46,000
17	107 +j 118 = 161	Same	26	26	.162	2.8	.66	.162	2.8	.66	1.9	241	55,700
18	73.5 +j 120 = 141	Same	26	26	.185	2.5	.521	.185	2.5	.521	2.4	270	50,000
19	793 +j1390 = 1600	Same	115	115	.072	4.1	.495	.072	4.1	.495	0.22	323	30,000
20	100 +j 115 = 150	Same	26	26	.18	3.0	.6	.18	3.0	.6	.....	.....	35,000
21	2000 +j1900 =2800	Same	115	115	.042	3.5	.73	.042	3.5	.73	0.68	3800	17,700
22	2675 +j1725 =3180	Same	115	115	.036	3.5	.841	.036	3.5	.841	0.45	3800	39,500
23	1250 +j1780 =2175	Same	115	115	.0529	3.5	.575	.0529	3.5	.575	0.16	3800	44,100
24	1575 +j 960 =1845	Same	115	115	.062	6.1	.854	.062	6.1	.854	0.75	2170	31,000
25	1478 +j1170 =1185	167 +j 91 = 190	115	28	.061	5.5	.785	.147	3.6	.875	7.2	218	27,800
26	112 +j 102 = 152	Same	24	24	.158	2.8	.74	.158	2.8	.74	12.4	206	31,000
27	1780 +j 852 =1970	Same	115	115 / 57.5	.0585	6.1	.92	.0585	6.1	.90	0.62	2170	32,600
28	490 +j 890 =1030	Same	115	115	.112	6.1	.49	.112	6.1	.49	0.32	2200	21,000
29	760 +j1030 =1280	Same	115	115	.090	6.1	.594	.090	6.1	.594	0.25	2170	100,000
30	385 +j 670 = 770	Same	115	115 / 57.5	.150	8.5	.50	.150	8.5	.50	0.45	1540	20,700
31	825 +j1052 =1337	3299 +j4210 =5349	115	230 /115	.086	6.1	.62	.043	6.1	.62	0.058	8672	61,500
32	803 +j 790 =1130	Same	115	115	.102	8.3	.71	.102	8.3	.71	1.65	1590	78,500
33	973 +j 695 =1197	Same	115	115	.096	9.0	.825	.096	9.0	.825	1.3	1470	47,500
34	760 +j 717 =1045	Same	115	115 / 57.5	.110	9.2	.73	.110	9.2	.73	1.83	1438	39,700
35	280 +j 575 = 640	Same	115	115	.180	9.1	.43	.180	9.1	.43	0.55	1460	47,800
36	315 +j 403 = 510	Same	115	115	.225	16.0	.61	.225	16.0	.61	0.6	830	58,700
37	240 +j 345 = 420	Same	115	115	.274	18.0	.57	.274	18.0	.57	0.78	735	28,400
38	532 +j 707 = 885	Same	115	115	.130	9.0	.60	.130	9.0	.60	0.36	1470	36,000
39	288 +j 359 = 460	661 +j 810 =1045	115	115 / 57.5	.250	18.0	.63	.110	8.0	.63	0.29	1653	35,000
40	158 +j 239 = 286	Same	26	26	0.92	1.6	.551	.092	1.6	.55	1.2	539	

Footnotes, cont.

5. When total ambient + motor rise does not exceed 135° C. Higher temperature motors available to meet individual requirements.

6. The specific manufacturers listed are those whose data are presented in the chart. Usually, most of the varieties of motors listed are available from most of the manufacturers listed. Code letter "X" means generally available.

7. Temperature range specified for intermittent motor operation.

TABLE III

FUNDAMENTAL FORMULAS FOR LINEAR MOTORS

ITEM	FORMULA	DISCUSSION
EFFECTIVE RESISTANCE	$R=\frac{Z}{pf}$	Unity power-factor parallel-tuned control impedance at stall. The resistance value into which the driving amplifier would operate.
TUNING CAPACITOR	$X_c=\frac{Z}{\sqrt{1-pf^2}}$	Value of capacitive reactance required to achieve unity power when paralleled with the control winding at stall.
POWER FACTOR	$pf=\frac{W}{VI}$	Cosine of the phase angle of motor impedance. The "Q" of the motor winding is the tangent of the phase angle. $Q=\sqrt{1-pf^2}/pf$
DAMPING (theoretical)	$D=\frac{T_s}{N_o}\times 6.743\times 10^5$	Damping is a measure of reduction in torque with increasing motor speed. "Theoretical" damp is the ratio of stall-torque to no-load speed under rated conditions. Damping is explained in more detail in text.
THEORETICAL STALL ACCELERTION	$A_s=\frac{T_s}{J}\times 7.062\times 10^4$	This ratio of rated stall torque to moment of inertia is a measure of the motor's ability to follow rapid acceleration in the input to the servomechanism.
TIME CONSTANT (theoretical)	$T_m=\frac{J}{D}$	Since damping is nonlinear, time constant varies with speed and control voltage. Theoretical value is good for comparison. Measure of time for motor to come up to speed.
REVERSING TIME (theoretical)	$T_R=T_m\ (1+\log_e 2)$ $\cong T_m(1.69)$	Time to go from full speed in one direction to 63% of full speed in the opposite direction when the control voltage is suddenly reversed.
POWER OUTPUT	$P_o=338T_sN_o$	Maximum watts output of a servomotor with a straight-line speed-torque characteristic occurs at ½ no-load speed with ½ stall-torque output. Maximum power is increased for curved speed-torque characteristics, occurring at higher speeds and relatively higher torques.
SYNCHRONOUS SPEED	$N_s=\frac{120f}{P}$	Theoretical upper limit of speed of a two phase servomotor. No-load speed is about $(5/6)N_s$.

NOTE: *Items marked "theoretical" are analyzed on basis of idealized performance characteristics, and are, in many instances, quite approximate. However, they do serve as a simple basis for comparison.*

LIST OF SYMBOLS

- Z *motor impedance, ohms*
- pf *power factor of motor, or cosine of impedance angle*
- X_c *tuning capacitor required for unity power-factor, ohms*
- V *voltage, volts*
- I *current, amperes*
- D *damping, dyne-cm-sec/rad*
- A_s *stall acceleration, rad/sec²*
- T_s *stall torque, ounce-inches*
- W *rated phase power, watts*
- J *rotor moment of inertia, gm-cm²*
- T_m *time constant, seconds*
- T_R *reversing time, seconds*
- f *frequency, cycles/second*
- p *number of poles*

FIGURES OF MERIT OF THE SERVOMOTOR AND SOME SELECTION CRITERIA

1. When the motor drives a negligible load, the maximum acceleration the load can accurately track is the theoretical stall acceleration divided by the gear ratio.
2. When you want maximum acceleration of an inertial load, J_L the optimum gear ratio is $(J_L/J_m)^{1/2}$, where J_m is the motor inertia. The maximum load acceleration for this ratio is $T_s/(J_mJ_L)^{1/2}$. In this instance, the ratio of stall torque to the square root of motor inertia constitutes a figure of merit.
3. Where you need a motor to track servomechanism input signals out to high frequencies, a minimum time constant is a measure of quality. The relation of reversing time to time constant is a simple proportion.

List of Manufacturers

Making SAE and BuOrd-Type Instrument Servomotors

This buyers' guide lists manufacturers producing a broad line of SAE and BuOrd-type standard instrument servo motors equipped to make special variations, or manufacturing important unique types—products covered in this Components Digest. It by no means includes all servo motor manufacturers.

Data in the Summary Performance Charts are representative of what is available within given size and power ratings. Direct negotiation with manufacturers is essential for finalizing motor selection.

The letter preceding the company name is the code identifying the company in Chart CD-I-1, column 4: "Manufacturer by Code." (See page 44.)

A **American Electronics Inc.**
655 W. Washington Blvd., L.A. 15, Cal.

B **Minn. Honeywell Reg. Co., Boston Div.**
1400 Soldiers Field Rd., Boston 55, Mass.

C **Clifton Precision Prods. Co., Inc.**
Marple at Broadway, Clifton Hts., Pa.

D **Daystrom Transicoil Corp.**
Worcester, Pa.

E **Diehl Manufacturing Co.**
1221 Finderne Ave., Somerville, N.J.

F **Dynamic Instrument Corp.**
59 New York Ave., Westbury, N.Y.

G **Eastern Air Devices, Inc.**
385 Central Ave., Dover, N.H.

H **Bendix Aviation Corp., Eclipse Pioneer Div.**
Teterboro, N.J.

I **Thomas A. Edison Industries, Instr. Div.—McGraw-Edison**
81 Lakeside Ave., W. Orange, N.J.

J **Ford Instrument Co.**
31-10 Thomson Ave., Long Island City, N.Y.

K **G-M Laboratories, Inc.**
4300 N. Knox Ave., Chicago, Ill.

L **Helipot Corp.**
Newport Beach, Calif.

M **Induction Motor Corp.**
570 Main St., Westbury, N.Y.

N **Kearfott Co., Inc.**
Little Falls, N.J.

O **Kollsman Instrument Co.**
80-08 45th Ave., Elmhurst, N.Y.

P **Muirhead Instrument, Inc.**
677 5th Ave., New York 22, N.Y.

Q **Norden-Ketay, Precision Component Div.**
Commack, N.Y.

R **John Oster Mfg. Co.**
1 Main St., Racine, Wisc.

S **Servomechanisms, Inc., Mechatrol Div.**
625 Main St., Westbury, N.Y.

T **Basler Electronics, Inc.**
601 Fifth St., Highland, Ill.

U **American Electronics, Inc.**
655 W. Washington Blvd., L.A. 15, Cal.

V **National Pneumatic Co., Inc., Holtzer Cabot Motor Div.**
125 Armory St., Boston, Mass.

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For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

• Standard External Cotters. Data sheet describes fifteen standard external, or "hairpin" cotters and prices and dimensions, wire sizes, pin diameters and lengths, and several new cotters not previously listed as standard by the company are given. Hunter Spring Co., Lansdale, Pa. Circle 150.

• Hi-Pressure Pilot Controlled and Relief Venting Type Regulators. Two new regulators for controlling high pressure gases are available in two inlet pressure ranges: to 3600 psi and to 7000 psi. The LR series loading regulators are designed for "dead end" and low capacity testing (2scfm.) of pneumatic components and for operating gas systems. Victor Equipment Co., San Francisco, Calif. Circle 151.

• 115-Volt, 400-Cycle Size 15 Inertia-Damped Servomotor. Size 15 inertia-damped servomotor is an a-c two-phase control component engineered to provide acceleration and deceleration damping in high speed and/or high gain servo systems without degradation of motor performance. Beckman-Helipot Corp., Newport Beach, California. Circle 143.

• Precision Angular Divider. Usable for exact angular positioning of synchros and potentiometers, this unique mechanism features an angular error of less than 20 seconds of arc relative to any starting position. Theta Instrument Corp., East Paterson, N.Y. Circle 218.

• 10-Watt Servo Motors. Designed for servo systems requiring sensitive and continuous control of load, four motors are available in 10-watt ratings: high and low-voltage units offered for use with 60 or 400 cycle systems. Ford Instrument, L.I.C., N.Y. Circle 219.

• Dual-Mode Excitation System for A-C Generator Control. Added to the exciter of an a-c generator set, the system offers faster response, extra power when needed, improved stability and longer regulator life. Electric Regulator Corp., Norwalk, Conn. Circle 222.

• Bobbinless Precision Wire Fixed Resistors. Detailed comparative data report shows that CTS bobbinless precision wire fixed resistors far exceed proposed MIL-R-93B, describes and illustrates 20 rectangular and tubular resistors and includes cutaway section picturing new "floating element" construction. Chicago Telephone Supply Corp., Elkhart, Indiana. Circle 140.

• Modular Oscilloscope Catalog. Modular oscilloscopes are described in a short form catalog and nine modules are shown including square and round CRT units, power supplies, and interchangeable amplifier and sweep modules which can be purchased separately or pre-assembled in a variety of single and multi-gun combinations. Advanced Electronics Mfg. Corp., Los Angeles, Calif. Circle 146.

• Rotary Servo Actuator. These actuators utilize a continuously-rotating motor, a-c or d-c, which drives two magnetic-particle clutches geared to a common shaft connected to the output shaft through a parallel gear train. Lear, Grand Rapids Division, Grand Rapids, Mich. Circle 220.

• Linear Servo Actuator. A continuously rotating motor drives the Lear "Siamese" clutch, which incorporates two clutches in one design. Clutch outputs are geared to a common output shaft, with an idler on one side of the clutch to provide reversal. Lear, Grand Rapids Division, Grand Rapids, Mich. Circle 221.

• Servo Null-balance Digital Indicating Instruments. With the proper transducer, variables such as force, weight, temperature and flow can be measured. Performance Measurements Co., Detroit, Mich. Circle 216.

• Miniaturized Silicon Transistor Servo Amplifier. Weighing less than one ounce with a volume less than ¾ cubic inches, these units require 28 volts d-c at 60 mills for full output, possess a voltage gain of 150. Librascope Inc., Glendale, Calif. Circle 217.

• Snap-Acting Precision Switches. Catalog folder describes line of miniature snap-acting precision switches. Types shown are: general-purpose, high-sensitivity, immersion-proof, metal-cased, reset, a-c/d-c, automatic-appliance, and AN-JAN Switches. Unimax Switch Division, The W. L. Maxson Corp., Wallingford, Connecticut. Circle 134.

• Bimetal Thermostats. Bulletin describes the operating principle and the construction of Type S thermostats and lists the various styles, applications, mountings, terminal arrangements, calibrations and ratings. Line drawings give all leading dimensions and show many popular optional features now available. Stevens Manufacturing Company, Inc., Mansfield, Ohio. Circle 135.

• Epocast Coatings. Epocast coatings, sealants, adhesives and pastes, are widely used in many industries: aircraft, missile, marine, transportation, food and chemical processing, metal fabrication, electroplating, industrial waste disposal, clay, ceramic and concrete fabrication and construction. Furane Plastics Inc., Los Angeles 39, California. Circle 136.

• Fine Wire Folder. Discusses the various factors that must be accounted for in drawing fine wire to 0.001 inch including use of diamond dies to draw the wire to a bright, uniform finish. Nessor Alloy Products Co., Newark 2, N. J. Circle 137.

• Gauge Saver. Automatic shut-off valves for overload protection of gauges and instruments in hydraulic and pneumatic systems in six models offer pressure ranges from 10 to 10,000 psi. Sprague Engineering Corporation, Gardena, California. Circle 138.

• High-flow Lox/Gox Test Facility. Cyrogenics facility, first commercial facility for testing ICBM and other weapon system components with actual media, provides liquid oxygen flow up to 8000 gallons per minute and gaseous oxygen flows up to 40 pounds per second and also offers combined functional-environmental testing. Wyle Associates, El Segundo, California. Circle 139.

• Portable Power Flarer. Portable, motor-driven unit for flaring tubing easily and accurately in the shop, in the mine or in the field may be clamped in a bench vise for convenience, or held in the hands when necessary. Parker Fittings & Hose Division, Parker-Hannifin Corp., Cleveland 12, Ohio. Circle 129.

Liquid-Filled Potentiometers. All working parts of new potentiometers are sealed in an oil bath which effectively cushions the unit against shock and vibration, increases dielectric strength, and flushes away wear particles that can reduce life and cause noise. Helipot Div., Beckman Instruments, Inc., Fullerton, Cal. Circle 223.

Transistorized Time-Delay Relays. Employing transistor circuits, these subminiature time-delay relays have no moving parts except relay contacts. Available with time delays from 0.01 to 60 seconds, the units will withstand 50 G shocks; vibration up to 2000 cps at 20 G. Tempco Instrument, Inc., Levittown, New York. Circle 224.

Adjustable Speed Drives. Rated from 3 to 200 hp for a single or multi-motor applications, motor-generator type adjustable speed drives combine the convenience and economy of a-c power with the versatility of d-c power. Drives incorporate standard speed ranges up to 8 to 1 by armature voltage control. Square D Company, Milwaukee, Wisconsin. Circle 225.

1200F Thermistors. Available in bare form with attached leads and without glass coating, 1200F thermistors have a resistance of 250,000 ohms at 25C, 0.7 dissipation constant, and a 2 second time constant. They can be used up to 1800F with moderate stability. Fenwal Electronics Inc., Framingham, Mass. Circle 226.

Digital Computer Control and Data Logging. This brochure describes the RW-300 digital control computer which can handle up to 1,024 analog inputs and up to 128 analog outputs, and discusses process control, data logging, pilot plant, and test facility applications for computer control systems. Thompson-Ramo-Wooldridge Products Co., L. A., Cal. Circle 227.

Subminiature Selenium Diodes. Developed for applications where ambient temperature is high, these units operate in an ambient temperature range of −50C to +100C, have 48 to 384 volts peak inverse voltages and 250 ua to 28 ma d-c forward current. International Rectifier Corp. Circle 228.

Economical Tantalum Capacitors. For applications where wider capacity tolerances are permissible, a new series of −15% to +75% tolerance tantalum capacitors have series resistance characteristics equivalent to other tantalum capacitors. Fansteel Metallurgical Corporation, North Chicago, Illinois. Circle 229.

Portable 5″ Oscilloscope. Having a 6 mc response, a portable scope has a high vertical sensitivity that permits display of a full inch of amplitude with a 10 millivolt input signal, and a triggered sweep which allows an input signal to initiate the sweep without the use of a vernier setting. Hycon Electronics Inc., Pasadena, Cal. Circle 230.

Transistor Servo Amplifier. Particularly suited for controlling small servomotors in high-performance instrument control systems, transistor servo amplifiers have a voltage gain of 100, an input impedance of 100K, a ¾ watt output and a weight of less than two ounces. Librascope Inc., Glendale, California. Circle 231.

Miniature Hexagonal Connectors. Designed for use in small electronic instruments, portable field equipment and aircraft where fast, easy, circuit disconnection is required, this series is available with four, five and seven contacts, and accepts #18 AWG wire. DeJur-Amsco Corporation, Long Island City, N.Y. Circle 232.

10.7 Megacycle Crystal Filters. Bulletin shows vacuum tube and transistor circuitry, pulse and impulse response photographs, attenuation versus frequency curves, and block diagrams of 10.7 mc crystal filters available in 30 kc, 15 kc, 6 kc, and 3.5 kc 6 db bandwidths. Hycon Eastern Inc., Cambridge, Mass. Circle 233.

Industrial Electronic Counter. Low-cost industrial electronic counter available in 4-digit or 5-digit models has a counting rate of 1 to 120,000 events per second for rpm or frequency counting, totalizing and time interval measurements. I.L.S. Instrument Corporation, Cleveland, Ohio. Circle 234.

Sealed Resistors. Precision wire-wound resistors are hermetically sealed in a glass envelope by bonding glass-kovar header to high-thermal, shock-resistant glass housings. Available in ¼, ½, 1 and 2 watt sizes with tolerances of 1% and 0.1%, the resistors are completely humidity proof. Networks Electronic Corporation, Van Nuys, California. Circle 245.

Computer Language Translator. 4-page bulletin describes the application, operation, and economical building-block design principle of the computer language translator system which makes possible the integration of computer and data-processing systems with normally incompatible formats. Electronic Engineering Company, Santa Ana, California. Circle 239.

Resistance Bridge Indicator. A self-balancing, compact instrument measures outputs of resistance bridge transducers in the range of 50 to 1000 ohms. A digital readout displays outputs from full or half bridges with 1, 2, or 4 active arms. Datran Electronics, Manhattan Beach, Calif. Circle 238.

Static Flashers. Two basic static flashers employ no relays or mechanical switching elements, are not subject to radio interference, have no moving parts and weigh less than 25% of obsolete, conventional types. Electronic Specialty Co., L. A., Cal. Circle 236.

Low-Voltage Control. 24 volt a-c control of power and lighting circuits from any number of remote stations can be achieved through use of a low-voltage control arrangement. Automatic Switch Co., Florham Park, New Jersey. Circle 240.

High-Speed Automatic Wire Cutter and Stripper. 4-page bulletin entitled "World's Fastest Wire Cutting and Stripping Machine", describes the machine and gives specific information on production rates—up to 9000 pieces per hour—versus wire lengths up to 120 inches. Jennings Machine Corporation, Philadelphia, Penn. Circle 241

12-KVA Slip Drive. Six-pound constant-speed drive designed for use in narrow-speed-range engine applications such as helicopters, turboprops, air-breathing missiles and drones has a 12,000 rpm output speed. General Electric Co., Schenectady, N.Y. Circle 242.

Analog-Punched Tape System. Flexible, data convertor designed to meet requirements for a rugged, economical, low-speed, data-processing system converts d-c data to 8-level punched tape and scans 20 data inputs at a 5 per second rate. Electronic Engineering Co., Santa Ana, Cal. Circle 243.

Miniature Sensitive Relay. Designed to operate efficiently on d-c coil signals at sensitivities from 20 to 100 milliwatts, this relay is available with either single-pole double-throw, or double-pole double-throw switch arrangements. Comar Electric Company, Chicago, Illinois. Circle 244.

Microhmmeter. A rugged, direct-reading microhmmeter has two ranges: 0 to 200 microhms and 0 to 2000 microhms. A linear 100 division scale indicates resistance directly and is unaffected by line-voltage variations. Sunshine Scientific Instrument, Philadelphia, Penn. Circle 237.

CLIFTON PRECISION SIZE 8 ROTARY COMPONENTS

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MORE THAN 30,000 SHIPPED TO CUSTOMERS OVER THE PAST THREE YEARS

ACTUAL SIZE

SERVO MOTOR	SERVO MOTOR	MOTOR GENERATOR	DC MOTOR	LINEAR TRANSFORMER	TRANSMITTER	RECEIVER	CONTROL TRANSFORMER	DIFFERENTIAL	RESOLVER
Input Power (total) 3.8 watts	Input Power (total) 5.6 watts	Generator: Input Voltage 10 v	Output Power 4.0 watts	Linearity .5%	Accuracy 7' error max.	Accuracy 30' max. error spread	Accuracy 7' error max.	Accuracy 7' error max.	Accuracy 7' error max.
Stall Torque .15 oz in min. .20 oz in nom.	Stall Torque .3 oz in min.	Output Voltage 0.13 v /1000 rpm max.	No Load Speed 20,000 rpm	Null E at EZ .015 v	Null 30 mv max.	Torque Gradient 2200 mg-mm/ deg.	Null 30 mv max.	Null 30 mv max.	Null 30 mv max.
Max. Weight 29 gms.	No Load Speed 6500 rpm min.		Input Voltage 28 v DC	Phase Shift 15 deg. lead	Phase Shift 8.5 deg. lead	Input Power .54 watts	Phase Shift 8.5 deg. lead	Phase Shift 9 deg. lead	Phase Shift 11 deg. lead

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